AID BOOK

TO ENGINEERING ENTERPRISE ABROAD

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EWING MATHESON

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PREFACE.

THIS book has been written from an Englishman's point of view as an aid to those who may be interested in the projection of engineering enterprises in foreign countries. The intimate relations which arise between the promoters of new undertakings abroad and the English engineers, capitalists, and contractors upon whom they depend, render it important that all those concerned should be in full accord. Too often, foreign or international transactions are hindered by the insufficient knowledge, on one side or the other, of the necessary facts; and in the following pages it is attempted to classify and link together those technical and economical conditions which determine the success or failure of Public Works and Engineering ventures; and especially to enumerate those preliminary particulars on which alone designs and estimates of cost can be framed.

It is intended in a Second Part, or sequel, to draw attention to the more important considerations by which the choice of engineering material and appliances for use in foreign countries should be guided; and to elucidate some of the incidents connected with their exportation.

The Author is glad of this opportunity to acknowledge the assistance he has received from many friends in regard to various special subjects.

LONDON, February 26, 1878.

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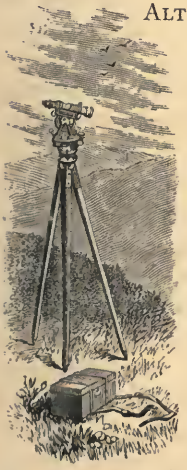
MATHESON'S AID BOOK.

IT is intended to publish in 1879 the Second Part, or sequel, referred to in the Preface. This Second Part will complete the plan of the Aid Book, and will treat—specially in regard to the value and choice for exportation—of COAL, IRON, and STEEL; STEAM-ENGINES; RAILWAY EQUIPMENT and ROLLING-STOCK; MACHINE-TOOLS; IRON ROOFS and BUILDINGS; and of various other Engineering Appliances connected with Public Works.

CHAPTER I.

ENGINEERING ENTERPRISE IN GREAT BRITAIN. PARLIAMENTARY PROCEDURE FOR RAILWAYS. ENGLISH AND FOREIGN LEGISLATION COMPARED.



ALTHOUGH it is the purpose in the following pages to treat of foreign rather than of home enterprises, it may be convenient first to summarise such of the English usage in these matters as may serve as a basis of comparison elsewhere. For the inception of engineering undertakings, there have grown up, through long experience, regulations and conditions, many of which are now embodied in precise codes of law and rules of procedure. These rules may be of use even to those outside England who have to initiate large works, and who may adopt as equitable some of the principles, if not the precise details, of English practice. On the other hand, unless the differences of circumstance, locality, and security are properly apprehended, foreign enterprises and estimates of profit based on the success of similar undertakings in England will be found to fail in practice.

English usage.

The tendency of modern times in England has been towards the abolition of monopolies and the removal of the numerous restrictions which formerly hampered manufacturing industries, the great advantages that are implied in the term Free-trade being now recognised and accepted by the nation at large. The abolition of protective duties on imports has rendered materials and food of various kinds cheaper; the removal of the Excise limitations on the manufacture of bricks, glass, paper, and other commodities has

Free-trade.

extended these trades beyond the most sanguine expectations; and the repeal of the Navigation Laws has, by stimulating the shipping interest, given England her supremacy in the carrying trade of the world. No classes have benefited more from these changes than the English capitalists, manufacturers, and workmen, who find profitable employment from public works and engineering enterprises in all parts of the world.

The free export of coal and iron, and the free import into England granted to the goods of competing manufacturers even from those countries where reciprocity is refused, have proved so healthy an incentive to exertion and invention, that the staple industries of the English engineering trades find markets all over the world, which are practically closed to those foreign rivals, who—having high prices assured to them at home by so-called protective duties—find when trade is dull or insufficient that they are unable to compete in neutral markets with those whose prices are at a natural level, available to purchasers everywhere alike.

Protective duties.

But while the tendency in England during the present century has been thus in the direction of free-trade, restrictions of an entirely different kind have at the same time been growing up, of which the Mines Regulations Acts, the Education Acts, the Factory Acts, and the Compensation for Accidents Act, may be cited as examples. Although these Acts have been framed in the interests of the public, they none the less enhance the cost of coal, iron, and machinery, and have weighted many manufacturing interests in the competition with those foreign rivals to whom such restrictions are unknown. There are other laws which affect engineers and control their designs. Among these are the Board of Trade regulations for railways, the local regulations of river conservators and harbour commissioners, to all of which conformity is required. Moreover, there are rules of voluntary societies, which are in effect equally binding. Lloyd's rules demand, as a condition of registry, certain proportions, dimensions, and qualities of vessels; fire-insurance companies require particular arrangements in factories; the steam-boiler associations a certain margin of strength in boilers; and to all these, engineers, more perhaps than any other class, have to conform, to an extent that is not customary in regard to similar matters abroad.

Legislative restrictions.

Voluntary restrictions.

But while engineering projects are thus controlled by legislative, municipal, and voluntary enactments, equally striking is the contrast between English and foreign usage in the respect paid to vested interests. In an old-established and crowded country like England, large engineering enterprises generally involve considerable interference with existing rights, and can only be commenced and carried on by the authority of Parliament. Although during the fifty years following the introduction of railways the system of legislation in regard to these and kindred enterprises has been altered, simplified, and improved, yet from the first conception of a new undertaking, every step in advance is fenced round with elaborate precautions for the protection of those affected, the interests most carefully guarded being those of the owners and occupiers of land, who, if compelled to sell, become entitled to the utmost value of their property, and to compensation for incidental loss by severance. The nature of the precautions adopted may be exemplified by stating the prescribed course of parliamentary procedure in the case of a proposed new railway; rules of similar import being applicable to other large undertakings.

Vested interests.

Land-owners.

Local promoters, capitalists, or others who have determined on a new railway, generally, as a first step subscribe among themselves for the preliminary expenses, or ask subscriptions for the purpose from those most interested, or even at this early stage invite subscriptions for shares. The opinion of an engineer is asked as to the feasibility and cost of the new line, and the engineer makes a preliminary survey of the country with trial sections, marking one or more possible routes on the Ordnance map. If the information thus obtained prove sufficiently favourable to warrant further action, a certain route is adopted, the preliminary surveys and estimates of cost are revised, and plans and sections on a scale prescribed by law of not less than four inches to the mile, and a vertical scale of not less than one inch to 100 feet, are prepared, showing the line of railway. The existing Ordnance maps are often adapted, but it is only where the Ordnance map of the district in question is drawn up to four inches to the mile that such a small scale is adopted. All buildings have to be drawn to a scale of not less than one inch to 400 feet, so that where a smaller scale is used for the general plan, separate enlarged details have to be furnished. As it would be impossible at this early stage to define exactly the width and extent of land required, "limits of deviation" of 100 yards on each side of the line are delineated, and within these limits the engineer will be permitted, if the railway is authorised, to construct the necessary works. A book of reference to the plans has also to be prepared, containing the names of all

Railway schemes

Preliminaries.

Surveys.

owners, lessees, and occupiers of land or houses within the limits of deviation.

The plans, sections, and book of reference are printed, and copies of those portions affecting counties, towns, or parishes are deposited in each case with the clerk of the peace, parish-clerk, or other local functionary. **Notices.** Notices in a prescribed form have also to be served on the owners, lessees, and occupiers whose land is on the line, or is comprised within the limits of deviation, acquainting them with the nature of the undertaking and the manner in which it interferes with their property or rights. Moreover, as part of such notice, is a request that an answer be sent back, announcing consent, neutrality, or dissent with reference to the proposed undertaking, the answers having to be embodied by the promoters in a schedule for Parliament. **Advertised notices.** Notices have also to be inserted as advertisements in one newspaper in each county through which the line passes, and, if the railway touches more than one county, in one London newspaper, and in the "London Gazette." With the exception of the latter, where one insertion only is needed, all these advertisements must appear three times, namely, once in each of three successive weeks in October or November.

Private Bills. The project has to be set forth in what is termed a "Private Bill," in contradistinction to the "Public Bills," which relate to public or imperial measures; and as the promoters seek, by obtaining the sanction of the Legislature to their Bill, to transform it into an Act of Parliament (which is the term applied after it has passed both Houses, and received the Royal assent), authorising compulsory purchases and other interference with the rights of others, it is necessary to include in the Bill every power requisite for this purpose. A copy of the Bill, together with a copy of the plans, sections, estimates of cost, and book of reference, have also to be deposited in the Private Bill Office of the House of Commons, with the Clerk of the Parliaments for the House of Lords, at the office of the Board of Trade, and also—where tidal waters are affected by bridges, embankments, or otherwise—with the Marine Department of the Board of Trade. **Minister of Public Works.** There is no Minister of Public Works, so-called, in England; but many of the functions generally entrusted to such a Minister are in England performed by the Board of Trade, where there are permanent official engineers to examine the plans, to see that nothing in the laying out of the railway is prejudicial to the safety of the public, The official inquiry is at this stage confined to such matters as the crossing of roads and the arrangement of junctions; but if the railway be authorised and made, a stricter inspection of details takes place before the opening of the line for passenger traffic is permitted. For there have grown up during the years of railway-making, certain standards of fitness, which, in the interests of the public, are enforced—the strength of bridges, the length of stations, and the arrangement of signals being examples of the numerous points upon which conformity to rules is required.

Government engineers.

As some bar to idle or vexatious applications for Private Acts, a deposit of money, which may be termed "caution-money," or approved security, amounting for railways to 5 per cent. on the estimated cost of the undertaking, has to be made at a public office—that of the Accountant-General of the Court of Chancery; and this money is forfeited if, in case the railway be sanctioned, it is not completed within the time prescribed by the Act, or within any extension of time granted by a new Act, or unless the undertaking is, by permission of Parliament, abandoned. Even where abandonment is permitted, landowners are allowed compensation for any injury they may have sustained by the operation of the Act, such compensation being made to them out of the deposit-money before repayment to the promoters.

Caution-money. *See also page 35.*

The Bill, plans, estimates, and notices having been advertised, and deposited, as just described, on or before certain fixed days in the months of November and December, and the caution-money deposited in January, the application to Parliament is fairly launched, and must be proceeded with according to fixed rules, entitled "Standing Orders," in the session of Parliament commencing in February. The number of Private Bills presented to Parliament is so great, and the questions involved so numerous and complicated, that it has become more and more necessary that the preliminary investigation should be concluded before the measures come to the stage of discussion on their merits. Two permanent examiners are therefore appointed, whose duty it is to examine every Bill, and to decide whether the rules of procedure above described, and which are set forth in the Standing Orders, have been complied with, and to report thereon to the special committees deputed to receive them. While the Bill is before the examiners, the promoters are required to attend to prove that they have satisfied the prescribed conditions. This stage in the proceedings affords the first opportunity for those who desire to oppose the Bill to bring forward their objection that the Standing Orders of Parliament have

Standing Orders.

Examiners.

Opposition.

not been complied with in respect to the Bill. Landowners, rival companies, and others may, and frequently do, attend by counsel to argue, not on the merits of the undertaking, but that the preliminary conditions or Standing Orders have not been complied with. Opposition at this stage is not, however, confined to those whose interests may be directly affected, but, as the regulations of Standing Orders have been framed in the public interests, anyone may attend and draw attention to errors or omissions in regard to compliance other than errors directly affecting owners, lessees, or occupiers of land, which can only be noticed by those directly interested in the land. There are Parliamentary agents—generally solicitors—whose special business it is to manage Private Bills, and who support or oppose them as the interests of their clients may require. If the examiners report that the Standing Orders have not been complied with, the Committee on Standing Orders specially appointed each session, who receive the report, have to consider whether there be any reason why compliance should be dispensed with, and whether in their opinion the parties to the new undertaking should be allowed to proceed with their Bill or any portion of it, and, if so, under what conditions. Where exemption is granted it is generally because the omissions have been trivial, or because the public convenience would suffer by the stoppage of the Bill. If Standing Orders have not been complied with, and if no exemption from compliance is accorded, the Bill fails, and can proceed no further, although the promoters may start again in the next session of Parliament, if they choose. If the report is in its favour, the Bill is read a first time in that of the two Houses to which it is presented. All Bills, public and private, have to be presented to and sanctioned by both Houses of Parliament, and have finally to receive the Royal assent; the Private Bills for railways and similar undertakings being initiated in one or other House, as may be arranged by the authority of the two Houses. At the commencement of every session each House appoints, by means of a "Committee of Selection," committees of its members to consider and report upon Private Bills classified according to their kind. Those Bills which have passed the ordeal of "Standing Orders" are generally read a first and second time without opposition, and are at once referred to one of the committees for consideration. Those who intend now to oppose the Bill on the merits must present their petitions within a limited time after the first reading. The promoters may object to the *locus standi*, or right to be heard, of the petitioners, and—if the

Errors or omissions.

Examiners' reports.

First reading.

Adverse petitions.

Locus standi.

Bill be in the Commons—the petitions and objections are referred to other officials, called the Court of Referees, who decide the point whether the petitioners are or are not to be heard; and their decision on this point is final.

Referees.

In Public Bills the discussion and contest on the principles of the measure take place on the second reading, before the Bill is referred to a committee, and if a Private Bill is one of very great importance, it may also be discussed at this stage, and stopped if a majority so wills it. But this occurs rarely with Private Bills, which, if they have passed "Standing Orders," are read a second time and referred to a committee almost as a matter of course. The committee, having before them the plans and sections, and being assisted by large maps or diagrams, hear the evidence brought forward by the promoters and their counsel in favour of the project. The opponents of the Bill appear here also, and by their counsel argue, and by their witnesses attempt to prove, that the Bill should be rejected, the principal pleas generally being that the undertaking is not really needed in the interests of the public; that it will interfere unjustly with rival undertakings, with land, property, or other existing interests; that the engineering details are defective; and that the work cannot be constructed for the amount of the estimate. In arguing for or against the Bill, the "Preamble," which is equivalent to the "Declaration of Public Utility" usual in foreign schemes, is first considered, for Parliamentary powers are held to be in restriction of the liberty of the subject, and those who seek them have the onus thrown on them of proving the necessity. If it can be shown that the reasons adduced for the project are not correct or sufficient, the committee may determine that the preamble is not proved, and so report to the House; such a report having generally the effect of terminating the Bill. If, however, the preamble be proved, then the Bill is discussed, and such clauses as are obnoxious to the opponents contested step by step. In the interests of landowners, of rival companies, or the public, the conditions are often modified or new conditions imposed, so that if the Bill succeeds in obtaining the approval of the committee, it frequently does so in a somewhat different state from that in which it was first presented for examination. The Bill is then reported to the House as approved, the report is considered, and the Bill is then read a third time and passed.

Second reading.

Procedure in committee.

Preamble.

Discussion of clauses.

Third reading.

Having been thus passed in one House, the Bill has to be presented to the other, and to pass through the same ordeal of committee and approval, although there are slight differences in the procedure. For instance, objections to the *locus standi* of petitioners are, in the

Lords and Commons.

Lords, not considered by a Court of Referees, as in the Commons, but by the committee on the Bill when it meets. The verdict of its committee is by each House almost always adopted; but if the Bill is one which excites much interest, it is sometimes discussed in the full House, and decided by the vote of the majority. In such case a Bill may by a resolution of the House be referred back to the committee, or if the importance of the matter warrant it, be considered in a committee of the whole House, and if a majority so will it, pass, in spite of the previous adverse determination of the smaller committee. Although the Bill may be opposed when it is first presented, and at each of the three readings, and at the consideration of the committee's report, and at the final passing, the usual time for discussion and voting, if such take place at all in the House itself, is at the second reading. Opposition after the second reading and after passing the committee is very rare, and in the vast majority of cases the procedure beyond this point is only formal. If the Bill fails in either House it is lost, but if it be passed by both Houses of the

Royal assent.

Legislature it, as a matter of course, receives the Royal assent, and, as an "Act of Parliament," becomes law, the refusal of the Royal assent to Private Bills being practically unknown.

It is not intended here to enumerate all the conditions which must be fulfilled, but the foregoing is a brief summary of the process of legislation on railways in Great Britain. For Harbours, Docks, Tramways, Waterworks, and other large engineering enterprises, the procedure is very similar, special conditions and rules as found necessary by experience for these particular undertakings having been adopted and embodied in the Standing Orders. Certain kinds of undertakings—of which Water, Harbour, and Sewage Works; Parks, Embankments, and Piers may be cited as examples—are often projected by Corporate bodies, to whom certain facilities are granted in the matter of procedure. Thus when a Private Act is promoted

Facilities granted to Corporations.

by Commissioners, a Corporation, or others in the public interests, the money for the undertaking being raised by public rates, caution-money is not required as in those cases where undertakings are constituted for the pecuniary profit of shareholders or others. The number of Private Acts applied for in this way tends (1877) to increase.

Parliamentary procedure is always expensive, and where the progress of private Bills is opposed, the cost of obtaining an Act is sometimes enormous. In the case of Railway Bills which have been keenly contested, the cost has in some notable instances even approached £10,000 per mile; excessive expenditure appearing in this way at its worst where the expenses have to be divided over a short mileage. Even where there is no opposition, the mere routine expenses are so considerable, and bear so high a proportion to the entire cost of small undertakings, as to stop the progress of those that require legislative sanction. To meet cases of this sort, and for undertakings of which Gasworks or Waterworks in small towns, where there is no great interference with private interests, may be quoted as examples, the Legislature permits an easier process than that just described. "Provisional Orders of the Board of Trade," authorising such undertakings, are granted, if, on inquiry by responsible officials, the scheme appears equitable and desirable. Plans and particulars have to be deposited by the promoters at the Board of Trade in the month of November, somewhat in the same way as just described for Private Bills, but in a simpler and less expensive manner, and by the spring of the following year the examination of the scheme is concluded. About the month of June or July in every session a special Bill is promoted by the Board of Trade for confirming Provisional Orders, and in this Bill are included all the schemes which have been examined and approved since November, the expenses attendant on the passing of the necessary Act being borne by the Government. Sufficient opportunities, which need not be stated here, are afforded to those affected by any of the schemes, to oppose them, but almost invariably the schemes recommended by the Board of Trade are confirmed by Parliament, and are included in the general confirmatory Act. The Board of Trade decides in each case when it is presented to them whether the undertaking is one which may be properly sanctioned by Provisional Orders, and, if not, may at their discretion transfer the matter to a committee of Parliament for examination and further progress as an ordinary Private Bill; but the tendency in recent years has been to extend the use of this form of legislation in regard to engineering enterprises.

Excessive costs.

Provisional Orders of Board of Trade.

Confirmatory Act.

Other Legislative enactments have been framed to facilitate the making of small railways, where the landowners and other persons beneficially interested all consent; and in such a case the Board of

Trade (which is supposed to examine and amend the scheme in the interests of the public) grants a certificate permitting the railway to be made. The advantages expected from these facilities have not, however, been realised, for it has been found impossible in the great majority of cases to obtain the necessary unanimous consent. While, however, this system has been found inoperative in England, where vested interests are so numerous, it may be suitable and beneficial in a new or pastoral country where but few persons are interested in the land.

Railways Construction Facilities Act.

Before leaving this subject to deal with enterprises of various kinds in foreign countries, it may not be out of place to refer shortly to some characteristics of the English procedure which appear most significant. While public law-making may be, and often is, at the discretion or caprice of Ministers or Parliament, of a sudden and unexpected character, legislation for private undertakings cannot be so. All private measures are, by their publication, submitted—as has been seen—to criticism and comment long before Parliament meets, so that no one can complain that he or his class are surprised by any Private Act. The Standing Orders of both Houses are framed to prevent hasty legislation, requiring as they do, and as has been described in the preceding pages, that in order that Bills may be discussed in Parliament between February and August in one year, the notices shall have been given, and advertisements shall have appeared, in October or November of the year previous. In all these matters of procedure improvements have been made, which not only tend to the protection of private interests, but render the work of promoters easier. Not the least of the improvements has been the assimilation of the rules of the two Houses of Parliament, and the reference of all preliminary questions to the same set of permanent officials. In the opinion of many promoters, parliamentary agents, and others specially qualified to judge, further progress in this direction is needed. Joint committees of the two Houses are even now sometimes appointed to settle such questions as the amalgamation of railways, and if by some one tribunal of this sort all Private Bills could be discussed, the enormous expense now occasioned by the double inquiry would be avoided. But there is a not unnatural jealousy in both Houses concerning any proposed abandonment of their separate powers, and sooner than relinquish such powers directly, it is probable, if an increasing press of business force a change, that more of the real

English procedure reviewed.

Procedure simplified.

Joint committees.

work of investigating will be left in the hands of the permanent paid officials already referred to.

But while parliamentary committees do not form perfect tribunals, no one in recent times has charged them with wilful unfairness or corruption. Happily, in England, the public men who in both Houses make up the committees are, with very rare exceptions, of such a character as to command respect for impartiality, ability, and disinterestedness. It is doubtful whether any court could be constituted even in London, more satisfactory to business men than a committee of Peers, presided over by an experienced chairman. It is equally doubtful whether there could be any courts freer from suspicion than the average committees both of Lords and Commons, who administer a system of law, which has grown up to suit the special questions brought under their control.

Fairness of English system.

The further procedure in regard to English enterprises is too well known to need much description. A municipality, a company of capitalists, or others who have determined on some undertaking, and who have obtained their Act of Parliament as described in the foregoing pages, then procure from their engineer such further plans and specifications as will enable contractors to estimate the cost of the work, and upon such a basis tenders are invited. The competition may be limited to a few contractors who are known as capable by the engineer; or the competition may be thrown open by advertisement to all who choose to tender. That offer having been accepted which is considered to be the most favourable, the works are then commenced, and the contractor is paid in money or other values according to the terms of his agreement. The contract may or may not prove profitable: that is a matter for the contractor. The work after its completion may or may not prove remunerative: that is a matter for those who pay for it; but for most works of public importance the two aspects of the case are kept quite distinct. The reasons which have prompted contractors in England occasionally to accept payment in shares, obligations, or something other than money, are various. Sometimes it is sheer speculation, and the temptation of the nominally high prices which in such cases are generally obtained. As regards railways, however, and some other classes of works, the special regulations usually contained in the authorising Acts of Parliament with regard to the issue of debentures, have been the chief cause of such ventures. In most cases, debentures cannot be legally issued until the whole of the share capital has

Tenders invited.

Letting of contract.

Payment in shares.

Debentures.

been subscribed, and a certain proportion—usually one half—paid up; and in more recent railway legislation the stringency of this condition has been increased by the provision that not only must one half be paid up, but that such half shall include at least twenty per cent. of each particular share before any issue of debentures can take place. It frequently happens that difficulty is experienced in obtaining subscriptions from the public for shares in new undertakings, the revenue from which is largely a matter of speculation. In these circumstances the contractor—who may probably have taken the initiative in obtaining Parliamentary powers, and is principally responsible for all expenses up to the passing of the Act—subscribes either personally, or by his nominees, for whatever portion of the shares is not otherwise applied for, the money paid by him in respect of such shares being, perhaps, almost immediately returned to him as payment for work done. The issue of the debentures, which may be nearly sufficient in amount to defray the whole of the contractor's real outlay, is thus rendered legal; and, as a rule, investors are more ready to lend money on such debentures, and bankers to make advances, than upon ordinary shares. There have been enough successful ventures of this kind on the part of contractors, especially at times when money has been plentiful or speculation rife, to tempt similar action again, and railways so made have been numerous enough to be classed as "contractors' lines." But there have been also many disastrous failures, and such methods of promoting engineering enterprise are often looked upon in England with disfavour. It would certainly be erroneous to consider such arrangements as usual or approved.

Debenture issue limited.

Contractors' lines.

See BANKERS, *page 41.*

Failure of contractor.

In England, as elsewhere, the contractor may be, indeed, so impressed with the good prospects of an enterprise as to take a share in it, or he may help to provide some portion of the necessary capital on condition that the contract is given to him at a price which he deems profitable. If he be wise, he will keep these two matters quite distinct: he will share in the enterprise only so far as is within his means as an investor, and will only execute the work for what he considers a remunerative price to be paid him in money.

Contractor and investor.

But it is not the present purpose to refer further to what is customary in this country. Those who are concerned in such matters know what to do, or have ample means at hand for obtaining information and advice. In regard to very many foreign undertakings the course is not so clear, and to these cases attention will be now directed.

And as general principles of prudence are not confined to localities, what follows may in many instances apply equally well to home enterprises.

Foreign and English procedure compared.

All countries, according to their civilisation and the usages of the people, have, of necessity, laws and customs regulating those engineering works which affect public or private interests. The extent to which such enterprises require control depends of course everywhere on their nature and magnitude, and it has been shown how fully existing interests are studied in England; but there is one marked difference between the laws which regulate these matters in England and those which prevail in the foreign countries which most require English aid. In England there is an almost unlimited supply of capital ready for any enterprise which appears profitable, and if, for instance, a district is in manifest need of a railway, or a town of water-works, there are eager engineers, capitalists, and contractors to design and construct the works. Hence for the vast majority of works the Government of the country has no need to initiate or even to encourage enterprise, and so far as it interferes at all in such matters, does so only to regulate, control, or even forbid. In European countries of the first rank there are codes of laws and official regulations as strict and as well defined as in England. The continental Governments, in regard to railways and other large engineering works, may be said generally to exercise more control in the authorisation and management than in England. In these countries many of the railways are under State control, the State aids them by national funds, and promotes legislation which has in view the still further conversion of these large engineering undertakings into national property. Competition is not permitted to the same extent as in England, and there is everywhere more of what may be termed paternal control. Many of the earlier continental railways were constructed by English engineers and contractors, but there is now more home capital and skill available.

State aid.

Colonial public Works.

In those English Colonies which have their own Legislatures, the example of the parent country has been largely followed in the forms of parliamentary procedure by which new undertakings are sanctioned. But the Colonial Parliaments and Governments have much more to do than in England with the initiation of new works, and have also to assist in providing the necessary funds. This does not arise from any lack of enterprise among the colonists, but from lack of cheap money. There is not in the Colonies the same large class of private

Lack of capital in the Colonies.

Colonial loans.

See LOANS, *page* 30.

investors with available capital, and content with a safe four or five per cent. interest; and as those who have money in the Colonies can employ it actively in profitable undertakings, the current rate of interest for ordinary commercial transactions is always much higher than in England. Hence people are glad to take advantage of the abundant wealth in England, and to borrow, by means of their Government and Legislature, at a much lower rate than would otherwise be possible. The money is generally raised in the shape of a loan for which the credit of the Colony is absolutely and unconditionally pledged, and investors in England, who would not venture to embark their capital in a distant country in railways or other speculative enterprises beyond their control, will trust to the engagements of the Government who have invited the loan. Happily, the good credit of England is shared by her Colonies, which can (1877) borrow at from four to six per cent.

Crown Agents for the Colonies.

Most of the Colonial business in England is managed by the Crown Agents for the Colonies in London. The Crown Agents consist of two or more officials appointed by the Secretary of State for the Colonies, and these agents are aided by a sufficient staff of assistants and professional advisers. The Agents and their assistants are paid by salaries, and make no other pecuniary profit from their office; and as the total expenses of the establishment are provided by contributions from about thirty Colonial Possessions, in proportions according to the services they require, the cost to each is very little. The Crown Agents negotiate Colonial loans, arrange with English contractors for the construction of railways, purchase material for railways, harbours, bridges, or water-works, and generally perform the duties necessary for Colonies who depend on England for their supplies.

Colonial Agents-General.

Some of the larger representative or self-governed Colonies have appointed agencies of their own in London, consisting generally of an Agent-General and staff, who, besides attending to the business just described, promote emigration and attend to the political interests of their respective Colonies; but occasionally even in some of these cases the agents associate themselves with the Crown Agents for important or delicate matters, such as the negotiation of loans or the administration of railways.

But whether managed by the Crown Agents, or separately by their own special agencies, the business of the Colonies in England is administered independently of the Home Government, which (except that it has promoted the establishment of the Crown Agents) interferes neither with their loans nor with the public works or purchases to which the produce of the loans is applied.

See INDIAN GUARANTEES, *page 32.*

Public Works of India.

In India the principal railways have been constructed by means of private capital, but with Government guarantees. The Government of India thought it, however, expedient to abandon this policy, and has since constructed railways and other works out of current revenue or with money raised by public loan. The Local Governments and Administrations have a limited power of undertaking railways and other public works by means of capital borrowed on the security of local revenues; but the principal works are undertaken only when recommended by the Governor-General in India in Council, and sanctioned by the Secretary of State for India in London.

Crown Colonies.

In the smaller Dependencies of Great Britain, which are administered as Crown Colonies, where there is no Legislature, all public works have to be sanctioned by the Secretary of State for the Colonies in England. If sanctioned, the expenditure for minor works, such as the maintenance of roads, is made direct from the local revenues; but all large contracts and all purchases in England are arranged by the Crown Agents for the Colonies.

Fortified stations.

The works connected with the defences of fortified stations, such as Gibraltar, Malta, and Bermuda, are managed by the Engineering Departments of the War-Office and Admiralty in London, although the civil business even of these Dependencies is conducted by the Crown Agents for the Colonies.

Room for private enterprise.

While, however, the Colonial and Indian railways, harbours, and other important works, which are beyond the means of local revenues, are thus constructed by means of borrowed capital, or in the case of smaller Dependencies and fortified stations by funds voted by the Imperial Legislature, and while the carrying out of the works is paid for in money as regularly as in England, there is ample room for enterprise in many smaller affairs of the kind described in succeeding chapters, and which, besides the aid of the contractor, require that of speculative capitalists.

But in other foreign countries, and especially in those semi-civilised or newly-settled, the Government has very different duties to perform. The construction of roads, railways, harbours, and other works may be all important to the progress and prosperity of the country, and yet there may be neither skill nor capital available. Outside aid has

Foreign Works. *See* CONCESSIONS.

English aid invited.

therefore to be invited, and this can be done successfully only by offering facilities, granting concessions, and, in fact, permitting and assisting the foreign capitalist to perform the works and to reap the profits arising from them, leaving for the people of the country the general or indirect benefits which will result. Instead, therefore, of having, as in England, to satisfy rigid conditions, to conform to fixed rules, and to pay largely for land and compensation, the English capitalist has offered to him abroad, facilities and inducements which may be liberal, but which necessitate on his part the close inspection, the rigid inquiry, and the guarantees which in England he would be obliged to assent to rather than to demand.

Land facilities.

See LAND, *page 25.*

There are not in new or sparsely-populated countries the numerous and diversified vested interests which stand in the way of undertakings in England; nor are the vested interests which have grown up so strictly regarded; and especially is this the case with the most powerful of interests, that of the owners and occupiers of land. Abundance of land, and facilities for acquiring it, go far to compensate for the lack of capital and skill; and, indeed, many of the most successful engineering enterprises carried out in foreign countries by Englishmen, would have been impossible had it not been for the great facilities granted with regard to land.

CHAPTER II.

CONCESSIONS FOR ENGINEERING ENTERPRISES IN FOREIGN COUNTRIES. MONOPOLIES. SUBSIDIES. GUARANTEES.

Concessions defined.

THE word "Concession," which has been placed at the head of this chapter, is a general term, which is well understood now-a-days to express the grant or permission from a State or other authority, which alone can authorise the execution of any public work. Such enterprises are either those of public utility, such as Railways, Harbours, Bridges; or those of local utility, such as Water, Gas, or Drainage works.

Promoters.

In foreign cities or countries, the demand for works of these kinds may come directly from the Government or the inhabitants, or may be suggested in the first instance by those who hope to make a profit if they can only arouse a desire for the works in question. Those who procure the concession and thus initiate or lead the way in such enterprises are generally known as promoters. A large proportion of the railways and other public works in foreign countries have been constructed with English capital, and the promoters of new undertakings in all parts of the world continue to depend in a great measure upon England for the carrying out of their schemes.

Works constructed by public money.

In many foreign countries there are, as in England, ample means for paying for works of utility. A Government or Municipality may provide the money out of public funds, or may raise the money by taxes, imposts, or rates levied for the purpose. A few private capitalists may unite, or public contributions, small and great, if sufficient in the aggregate, may, through the ordinary machinery of a joint-stock company, be rendered available. In such cases as these, if English aid be sought, it is only for engineering skill to design, or for contractors with experience and means to carry out, the works, or for both these purposes. But it often happens that the necessary funds are not forthcoming, and the aid of the English capitalist, as well as that of the engineer or contractor, has to be obtained.

English aid required.

Deferred payments.

Perhaps the Government, or Municipality, may be able to pay, but only in obligations or bonds instead of in money; or although able ultimately to pay in money, cannot do so till the work in question is completed. In either case somebody must provide money to pay for the works during progress, and here the functions of the capitalist, or the capitalist-contractor, commence. There is a great variety of circumstances and combinations in these matters; and in this and the following chapters some suggestions are made with regard to the financial, local, and technical conditions which are essential to success.

Ample information necessary.

In asking consideration for any new scheme, the first duty of the promoter is to furnish ample information; and, simple as such a condition may appear, it is one seldom thoroughly appreciated. The following statement of what the preliminary information should include, applies generally to most engineering enterprises, and it will be seen throughout that five interests are in view, those of the public, the capitalist, the engineer, the contractor, and the promoter. It is impossible to distinguish exactly between these interests, as the functions of each class are often combined, or overlap those of the others. According to the manner in which an enterprise is presented for consideration, and the kind of aid which is sought, will the different suggestions in the following pages apply. The information which will be required may be classified as follows:—

Information classified.

1. The Nature of the Undertaking.
2. The Need for the New Undertaking.
3. The Terms and Validity of the Concession.
4. The Estimated Cost of the Undertaking.
5. The Nature and Amount of the Payment or Profit.
6. Under what Control and Jurisdiction the Works are to be executed and maintained.
7. The Price or Consideration to be paid for the Concession.

Nature of the undertaking.

1. *The Nature of the Undertaking.*—The work having been specified as Railway, Harbour, or otherwise, the extent and objects of the works should be stated. The detailed technical and local information required is described in succeeding chapters, under the respective headings of the various undertakings.

2. *The Need for the New Undertaking.*—It is obvious that enterprise directed towards the supply of an indisputable want, is more

likely to succeed than where—other conditions being equal—the need is problematical, or is not obvious. If the want in the localtity is not sufficiently notorious, and if, as a justification for the new enterprise, the success of similar schemes elsewhere is adduced, evidence will be required to show that the circumstances of the different localities are sufficiently alike to warrant the representations of the promoter. But even if there is the assurance of good management under conditions seemingly as favourable as before, it is necessary to show that there is sufficient scope for the new enterprise. Of the various points of view from which such cases will have to be regarded, two examples may be given. A railway may be projected in a district where an existing railway already runs, and although the new line may pass through different towns, it may interfere with or rival the older undertaking. The commerce, existing or probable, of the locality may not within a reasonable time be able to provide sufficient traffic for the two, and the rates for even this diminished traffic may, by the new competition, be reduced. Or, to take another example, capital may be sought to work a quarry of marble of a very high quality. It may be indubitably shown that similar marble sells for forty shillings per cubic foot, and it may be proved with equal clearness that every week five hundred cubic feet of marble can be got from the new quarry at a cost of twenty shillings per foot. The calculation of profit appears easy. But there is probably only a limited demand for so high a quality of marble; new customers for five hundred feet per week may not easily be found; and the new quarry will only be able to share in the trade of the existing quarries. But more than this, the buyers of marble hearing that capital is being sunk in a new quarry, will postpone their purchases in the hope that the coming competition will reduce prices; an immediate reduction in price will probably be the result; and the proprietors of the new quarry may find, when they are ready to sell, that the mere anticipation of their sales has caused the market price of this kind of marble to fall; and that they can only sell one hundred feet per week, at a price of thirty shillings per foot. Of course an example of this kind applies with less force to an article in common demand, such as coal, iron, or copper; but the same principle applies in most cases in some degree. And it must be borne in mind that an increase in the supply will generally have a more than proportionate effect on prices. Thus if in the corn market there is an increase of 5 per cent. in the supply, prices will probably fall more than 5 per cent., because of the

Need for new undertakings.

Insufficient scope.

Competing railways.

Over-supply reduces prices.

Scarcity raises prices.

Supply creates demand.

competition of all sellers to dispose of their stock. A scarcity tells as strongly in the opposite way, for if the supply be reduced 5 per cent., prices may rise 10 per cent., in the struggle of many buyers wishing to buy before the prices rise higher, and the comparative indifference of sellers to part quickly with their goods in a rising market. Weight must, however, be given to the fact that a supply sometimes creates a demand; and this especially is the case where a new enterprise is commenced in a thriving or growing community. A railway causes traffic that never existed before; a convenient harbour brings ships; gasworks awaken a desire for the improved light; a new market-hall tempts customers.

Terms of concession.

Validity.

3. *The Terms and Validity of the Concession.*—The kind of concession, or the terms on which the work is to be undertaken, must be fully set forth, and especially with reference to the conditions enumerated on pages 24 to 33. It must be shown that the official or other bodies who have granted the concession, have acted within their powers; and the confirmation should be produced of any Sovereign, President, or Assembly whose consent is necessary. To still further give satisfaction on this point, it must be shown that the concession does not clash with any granted previously, or with any existing privileges. Written concessions, documentary evidence of all kinds, and signatures, should admit of verification, and—in the case of countries not under British jurisdiction—should be so verified by notarial and consular declarations.

Estimated cost of works.

4. *The Estimated Cost of the Undertaking.* — In the case of railways, harbours, and other large works, preliminary surveys and estimates by competent engineers are necessary, and promoters should at an early stage obtain by these means at least some approximate idea of cost. They have therefore to decide upon the amount of money they will spend in these preliminary investigations. Sometimes, where similar works have been executed elsewhere under somewhat similar conditions, the experience so gained may be sufficient for preliminary purposes; but where such evidence stands alone, it is always received with hesitation. In cases, however, where structures or machinery form a large proportion of the scheme, where the local circumstances do not therefore form a very important element in the cost, sufficiently accurate estimates may be made in England, if the essential and easily-obtainable particulars are furnished. The nature of the information required for different kinds of works is described in each case as it occurs in

the following chapters. If, however, to obtain sufficient information, preliminary surveys are necessary, and the promoters having only furnished meagre information, invoke the aid of the capitalists to make these surveys, they will probably have to give the option of taking up the concession on certain terms, or otherwise bind themselves for a certain period to whoever so aids them.

Preliminary expenses.

Preliminary expenses fall properly on the promoters, and those promoters who show a disposition to share in the risks of a new enterprise are always listened to with more attention than are those who ask that all may be done for them. Such willingness is naturally taken as proof of confidence in the soundness of a scheme. So also the co-operation of local capitalists has weight. However poor a country may be, it seldom happens that there are not some who have means for profitable undertakings; and as people residing on the spot have special facilities for estimating the probabilities of success, and would—unlike the foreign capitalist—share in the indirect public advantages expected from the scheme, the absence of such home-aid suggests doubts as to the genuineness of the enterprise. There are, of course, exceptions to this rule in those cases where the local capitalists, never having seen similar undertakings before, or being ignorant of the benefits that will result, hesitate to join in an expenditure of which the returns seem to be problematical. So, also, there are cases where it is expedient to keep the capital within a limited circle.

By whom defrayed.

Assistance of local capitalists.

In estimating the cost of any new undertaking, sufficient margin must be left, not only for contingencies during construction, but for working capital and expense of management after completion, until sufficient revenue is forthcoming. Even if the spare capital be not called up, it is most important that it be available when required, as without it, money has often to be raised on onerous conditions, which absorb the profits of the enterprise.

Spare capital advantageous.

5. *The Nature and Amount of the Payment or Profit.*—This is obviously one of the most important matters in connection with a new enterprise, and as it is one which more than any other determines the adoption or rejection by capitalists of a project presented for their consideration, it is useless to present it unless full information on this point be furnished.

Payment and profit.

Where simple and secure money payments are offered in return for material to be supplied, for services to be rendered, or works to be executed, ordinary and well-known conditions of business will

See pages 11 and 15.

See EXPORT, *in Part II.*

Deferred payments.

Security wanting.

See page 51.

apply; and occasional mention is made of these in succeeding chapters. The regular money payments made to contractors in England and her Colonies have been already referred to; the conditions of payment usual in purchasing material for shipment to a foreign country will be also described further on. But in many of the foreign enterprises brought to England for consideration and adoption, the kind of payment or profit offered in return for the aid which is sought, is of an entirely different nature to the foregoing, mainly because such profit is deferred or speculative. The mere fact of having to depend on payments in a foreign country not under English jurisdiction, is in itself a cause of hesitation to many capitalists and contractors; but the facilities which now exist for international transactions render this difficulty a small one where legal remedies are as certain and as capable of enforcement as in England. A serious difficulty, and one which often forms a bar to English enterprise abroad, is the want of sufficient legal security, or the hampering of the concession or contract by conditions not usual in England, the risks of which are not easily measured.

Power of transfer needed.

See page 40.

Verification of earnings.

Capitalists generally value the payment or profit offered to them in proportion as it appears marketable or transferable to others. In some cases—and these are the really speculative ones—capitalists employ their own money temporarily in the hope of transferring their property in the undertaking at an enhanced price when they have developed it. In other cases they assure themselves of this transfer before they commit themselves to the enterprise. The separate functions of the contractor and the capitalist are further defined in another chapter; but in any case, if the work is to be paid for as it proceeds, the periods, conditions, and amounts of the payments will have to be very clearly defined; and when this stage in the negotiations is reached, the promoters must be prepared to give satisfactory information as to the ability and intentions of those who have to pay. If the profit of the capitalists is to consist, all or in part, of revenue to be derived from the work itself, very complete information on this point will be required; and as the evidence adduced will be subjected to rigid examination, the promoters must be prepared to show the data on which the calculations of expected earnings have been based, and to afford opportunities for verification. In cases where payments for a new undertaking are to be made without reference to future revenue, it is still desirable to furnish such information, so that if satisfactory, the capitalists or contractors may have the more confidence in the soundness of the undertaking, and in the ability of those interested to pay for the construction. It is never desirable to be connected with what may possibly become an unprofitable or unfortunate speculation, even if free from a share in the direct loss.

6. *Under what Control and Jurisdiction* the works are to be executed and maintained. It is necessary that the contractors or capitalists should have confidence in the ability and fairness of the engineer or other person under whose direction the works are to be carried on. In the case of works executed in foreign countries, the authorities who grant the concession frequently require that their own engineers shall control the execution, and, as a condition of payment, certify concerning the progress and completion of the works. It often happens, however, that the works have to be designed as well as carried out by English aid, and in such cases it is natural that the engineer who designed shall superintend the construction, and certify the completion. The justice of such a condition is still more evident when English capitalists provide the means, or an English contractor undertakes the work, and in such cases the capitalists or contractor will generally insist on the appointment of an English engineer, whose certificates shall be received. Not only, however, should the engineer be empowered to certify, but he should be bound to do so when the certificate becomes due; and provision should be made in case he is unwilling or unable to perform this necessary function. If the certificate is given by the engineer directly to those who are to pay, a copy of it should be delivered also to the contractor.

Control of works.

Engineer's certificates.

As the revenue to be earned by the undertaking will greatly depend upon proper maintenance and management, it is important for the capitalists or contractors—if their payment or profit is to be made out of revenue—to know that the management shall be efficient and trustworthy.

Maintenance and management.

As the ultimate appeal in case of dispute is always to the law, capitalists are interested in knowing by what law they will be bound during the execution of the contract. If they have doubts as to the stability, powers, or fairness of the courts which will have jurisdiction, they may probably require security of some kind in Great Britain, or in some neutral hands. Questions of this sort, and those concerning arbitration, are matters for consideration in every contract, and need not be further referred to here.

Appeal to law.

Jurisdiction.

Price of the concession.

7. *The Price or Consideration to be paid for the Concession.*—It sometimes happens that the capitalists or contractors treat directly with the public or other body which requires the works in question, without introduction by any third party. In such cases it may be that no payment or consideration has to be made beyond the works specified in the concession itself; but in many cases the earlier negotiations are carried on by persons locally interested, or by those who, having heard of a possibly profitable enterprise, arrange conditionally the terms of a concession, and then seek for capitalists to take it off their hands. This is a perfectly legitimate position when fairly taken up, and is often a source of considerable profit. In some cases, a promoter demands a specific sum as a consideration for introducing a profitable undertaking. If the profits appear very certain he may obtain payment at once, or may be content with deferred payments spread over a considerable period. The promoter, however, induces confidence by allowing his own profit to be dependent on the success of the enterprise. This may be arranged by postponing his own payments till the completion of the works, or—if the capital be raised by means of a joint-stock company—by taking his payment in shares or debentures, whose value will depend on the earnings of the undertaking. If a promoter is content with an equitable arrangement of this sort, he may at the same time stipulate for an immediate repayment of the actual expenses already incurred. If these are not unreasonable in amount, they may be treated as part of the general expenses of the undertaking, and paid for out of the new capital to be introduced. Whatever these payments may be, they should be explicitly and fully stated in all documents inviting public subscriptions.

Promoters' profits.

Payment to promoter deferred.

The capitalists may naturally stipulate for the assistance of the promoter during the construction of the works, and expect his influence in the negotiations as well during the progress as at the final settlement. This is another reason why some of the payments to the promoter should be postponed, so that it may be his interest as well as his duty to give his aid throughout.

A Government, a Province, or a Municipality may grant concessions in various ways:—

Concessions vary.

A simple Permission may be granted for the execution of the works, the concessionnaires being left to make their own arrangements for the purchase of land, rates of tolls, and all other necessary matters.

If the enterprise promises sufficient profit, this permission may be all that the capitalists will require, and if they have confidence in the laws of the country, and have no fear of anything like confiscation, they will construct the works, trusting either to sell them when completed, or to derive from them a sufficiently remunerative revenue.

Permission granted.

Facilities granted.

Facilities or Immunities may be granted.—The Government of a country may do much to assist and encourage works of utility even in those cases where the initiation and carrying out of works are left to private enterprise. Especially is the assistance of a Government needed in a new or unexplored country, to investigate its natural resources, to make surveys and maps, and to record the information thus obtained in a convenient form for reference. Engineering enterprise will follow more quickly if such information be afforded; a basis is created on which roads and bridges can be projected, and the further development of the country is greatly facilitated. Hydrographical charts, river explorations, and meteorological reports are equally important, and a Government which thus paves the way for public works, in most cases does more for the real advantage of the country than by spending the same amount of money directly in railways, telegraphs, and other works which are more likely to be successful when undertaken by private capitalists. But to these earlier services which fall within the legitimate province of a Government, must—if capitalists are to be satisfied—be added the essential safeguards of equitable laws, which ensure safety to person and property.

Government surveys.

Equitable laws.

In works covering any considerable extent of ground, the acquisition of the land is one of the first matters to be arranged, and one in which some official authorisation is necessary. Such authorisation is generally required in Great Britain, where railways and other public works are sanctioned by Parliament, which allows the compulsory purchase of land. Even in countries where the new undertaking is so welcome as to induce landowners to give their land gratuitously, it is well to obtain such powers as will overcome, if necessary, the possible opposition of any landowners. In some cases the Government or Municipality will give land or site gratuitously, or at a merely nominal price; the expropriation of the land, and the negotiations necessary for that purpose, being often undertaken by a Government, who guarantee the price and terms on which the land may be acquired, even in cases where they do not assist the

Land given gratuitously.

enterprise in any other way. A Government can generally obtain the land on easier terms than would be possible by concessionnaires, especially if they be foreigners, although in some cases it is at the expense of private rights. For in many foreign countries the State is not only paramount, but the individual is almost disregarded, and to aid in an undertaking which is declared to be for the public convenience, he is compelled to sell his land at an arbitrary price fixed by public officials.

Immunities granted.

Immunities also may be granted by the exemption from import or other dues of the tools and material to be used in construction, or by exempting for a term of years the revenue from taxes, or by allowing the use of Government wharfs, railways, or canals gratuitously or at favourably low rates.

Subsidies.

A Subsidy may be granted.—In some cases the undertaking may be of such importance to a country, a province, or a town, that the authorities will offer an inducement to foreign capitalists in the shape of a money payment. Such a subsidy may be made payable when the work is completed; but if the principle of a subsidy be admitted, and if the undertaking be a large one, payments at certain specified periods during progress are generally agreed upon. Sometimes the subsidy may not be in money but in land. A new railway or harbour; irrigation, drainage or reclamation works may be expected so to improve the adjoining land as to render it valuable. In such cases it is not unusual to share with the capitalists the land thus to be improved. In railways, for instance, alternate blocks of land on either side of the line are often pledged to the capitalists, and become their property as the line is completed. In a new country where land is plentiful, this is frequently an advantageous arrangement for both parties, and one easily adopted, because the land before the railway or other works are executed is generally of little value. It is the judicious selection of such surplus land with the view to future population and ulterior profit, that has rendered so many colonial or foreign railways practicable or possible. Land being capable of sub-division can be sold in large or small lots to suit purchasers; and bonds which represent the land, and prospectively pledge it as the works are completed, are thus available for large or small investors, who do not care to participate directly in the risks of the enterprise.

Grants of land.

Land-bonds marketable.

If engagements for subsidies are entered into with stable Governments whose credit is unblemished, they are of very great assistance in the raising of funds for the works; but subsidies are sometimes considered objectionable, as involving too much Government control or official interference.

Subsidies must be clear.

It is of course necessary in regard to all subsidies to see that the written engagements are clear, well defined, and within the powers and capabilities of the subsidising authority. If bonds which represent engagements are qualified by vague or numerous conditions, it is obvious that they possess little negotiable value for the investor who buys them. Where land is offered as a subsidy, it is especially important to ascertain that those who promise to give it have the right to do so, as cases are not unknown where land pledged by a Government has been afterwards found to be burdened by proprietary or other earlier rights.

Monopolies.

A Monopoly may be granted.—It happens sometimes that the mere giving of permission to execute works may, in effect, be the granting of a monopoly, as there may not be room for two undertakings of the same sort. A monopoly in express terms is of course the more valuable concession, as it is a protection either against rival schemes which may be projected simply to be bought up, or against the more or less legitimate rivalry at a future time when the profits may have so increased as to invite such competing undertakings. A monopoly is generally for a term of years; and if the nature of the undertaking requires it, is defined by distance, as, for instance, by miles on each side of a railway, or, in the case of a toll-bridge, by distance along the stream above and below the bridge. In some countries, where it is considered desirable to encourage the enterprise of capitalists, a monopoly for a term of years may be claimed as a right by whoever inaugurates a new industry.

For terms of years.

Objections to monopolies.

As a general rule it may be affirmed that the granting of monopolies is not an economical method of executing works of utility, and is not in the true interests of the public. But in a new or undeveloped country, where the undertaking is one of which the profits are speculative, the utility of the works executed may be such as to warrant some encouragement or security to the capitalists who are willing to speculate. In England monopolies are seldom granted, and railway shareholders, among others, complain that rival lines are permitted to invade territory already occupied, and to diminish profits. In France and many other countries, shareholders are in effect, even if not by direct legislation, protected from competition; but it is probable that the English system has, by the stimulus given to trade, proved more advantageous to the nation at large than the artificial protection given in France.

Enforced monopolies.

See BRIDGES, WATER-WORKS, MARKETS.

A Monopoly may be made absolute by Enforcement.—When the new undertaking is completed, those works previously existing which it is to replace, may be stopped. For instance, with a new harbour, the landing of all goods at it may be enforced; or all goods landed within a certain distance of it subjected to toll. With a new bridge, old roads may be directed to it; with new water-works, old conduits may be removed, or all houses compelled to use the new supply; if new markets are built, they may be made to cover the site of the old ones, or selling in the neighbouring streets may be prohibited; with new abattoirs, their use may be rendered obligatory.

Guaranteed revenue.

A certain Revenue may be Guaranteed.—A Government or Municipality may engage to use the new undertaking, and to pay tolls up to a certain agreed minimum. This may be done in the case of a railway, waterworks, bridge, or any undertaking which depends upon tolls or dues for profit. Sometimes the guarantee may proceed from landowners, merchants, or existing companies, who are interested in encouraging the new undertaking. In these cases where the guarantee proceeds from other than State or Municipal authorities, great care is necessary to make precise and safe engagements. It often happens that a minimum revenue thus secured is of itself sufficient to pay a moderate interest on the outlay incurred, and with this safe minimum, capitalists will be the more willing to incur some risk with respect to the possible surplus profit.

Guaranteed interest.

A certain Interest may be Guaranteed on a specified amount of expenditure. In countries too poor to raise the capital necessary for public works, there may be no insurmountable difficulty in paying interest on capital provided by others. If a Government, Municipality, or other public body, is willing to guarantee interest, it is to be presumed that the undertaking is much required, and is expected to be of great value to the community when completed. Perhaps this value may be shown directly in the shape of revenue sufficient to pay the interest; in other cases the undertaking may be remunerative only indirectly, by removing obstacles, promoting commerce, or otherwise. Such advantages may render a community, or those who are to be benefited, able and willing to pay tolls or taxes sufficient for the interest.

Various kinds of guarantees.

A guarantee may be granted in a variety of ways. Sometimes the merchants, landowners, or others who are interested in promoting the new work, will themselves provide a portion of the necessary capital; the Government or Municipality will guarantee interest on a second portion; and the capitalists who provide this second portion with interest thus secured, may be willing to provide the third and unguaranteed portion also, if upon it the revenue earned by the whole is pledged to pay them a preferential interest; or the guarantee may be only to the extent of a minimum interest, which, though not in itself sufficient to tempt investors, may so remove the risk of absolute loss as to render them willing to venture. Thus there may be an enterprise which in the mind of the investor is—if unguaranteed—of a character so speculative as to require a probable return of 12 per cent. to induce him to join in it. But if a minimum of 5 per cent. be secured to him, he may be willing to invest, even if he sees a probability of but 8 per cent. in all. A concession which guarantees interest is most popular with investors, and if the credit of the guarantors be sound, is more easily negotiated than a concession promising much larger but unguaranteed profits, or even than one granting a subsidy. When capital is raised in this way by a Government, the transaction resembles in some measure a public loan, and the interest it would be found necessary to offer for a loan may serve as an approximate guide to what is required in a guarantee.

Loans and guarantees compared.

But there are differences between a loan and a guarantee, which may be noted. A Government loan generally pledges the national credit absolutely and unconditionally, and the lender need have little concern in any public works which may be the occasion of the loan, unless, indeed, they are pledged as collateral security. But, on the other hand, the mere guarantee by a Government of interest on the capital of some enterprise in private hands—say on bonds issued by a company—will not always secure the acceptance of so low a rate of interest as would suffice on the national loan pure and simple. The guaranteed bonds are possibly hampered with conditions; they do not appeal to so wide a class of investors; they may not in the aggregate be of sufficient amount to be spread over many money markets; and, as less known, may be less negotiable, and therefore less valuable than ordinary Government stock. Thus if a Government be of such sufficient credit as to borrow at 4 per cent., it is not improbable, if they offer a guaranteed interest on the bonds issued by a private company, that 5 per cent. may be needed in order to make such bonds as saleable as the stock of a Government loan. These remarks obviously apply only where the guaranteed interest is alone under consideration. If besides the guaranteed minimum, a higher interest is expected from the enterprise itself, then of course a speculative value is offered to the investors apart altogether from that afforded by the guarantee. Moreover, capitalists or contractors who engage to receive guaranteed bonds in payment for works, incur certain expenses of discount and brokerage, and their price for the service rendered is enhanced accordingly. For these reasons, Governments who can borrow at a moderate rate of interest will often find it to their advantage to do so, rather than to pledge their credit indirectly in guarantees. It is in this way that so many of the English Colonies, borrowing in England at low rates under the guidance of the Crown Agents, and independently of financiers, have been able to construct State railways at a cost which only prompt money payments to the contractors renders possible. Comparing, however, one kind of loan with another, that in which money is raised for the specific purpose of public works of a remunerative nature will, if honestly managed, be more likely to be received with confidence than a loan raised to defray current expenditure, which may be applied to military or other unremunerative purposes. But even in the former case it is necessary sometimes that the investors should be protected against misappropriation of the funds, and they may require to be satisfied, not only that the entire works can be completed for the sum estimated, but also that the capital raised will only leave their custody, or that of trustees in whom they have confidence, on the certificate of a competent person that a corresponding portion of the work is accomplished.

Rates of interest.

See page 14

Different Government loans compared.

Provincial and Municipal guarantees.

Provincial or Municipal guarantees are sometimes more to be depended on than Imperial guarantees, subject to political influences or changes of Government; and it has thus sometimes happened that in countries where imperial guarantees and obligations have proved fallacious, a municipality or province has maintained a character for fair dealing. But although in certain cases the real comparative value of different guarantees may be thus stated, obligations or bonds of Imperial Governments are generally more easily negotiable because they are better known, and because such Governments are considered more amenable to diplomatic influence and public opinion.

Private guarantees.

Private individuals, corporations, companies, or the owners of existing properties, which are to be benefited by the new undertaking, sometimes give guarantees. For instance, the owners of a railway, or group of railways, may anticipate benefit from the construction of another railway, or of an important bridge, or of a harbour, and without themselves having the funds available for the purpose, may be so satisfied of its importance as to pledge their own revenue in addition to that anticipated from the works contemplated, so as to ensure a preferential interest upon the new capital. The revenue thus pledged may possibly have been so constant or progressive in the past as to be received almost as an absolute guarantee; but as a rule this latter is preferred, and investors will scan with great caution, not only the exact wording of a merely preferential guarantee, but the legal security which is offered for its fulfilment.

See BRIDGES, WATER-WORKS.

Preferential guarantees.

Whatever be the nature of the guarantee, it should be recorded as explicitly as possible. It much facilitates the raising of capital if a guaranteed interest or subsidy be expressed in well-defined bonds which can be made negotiable. The exact manner of doing this is, of course, a matter for arrangement in each particular case. A Government or Municipality, or any corporate body, which expresses its engagements in bonds, may word them either so that their liability comes into force only when the entire works are completed, or, as has been before stated, so that they take effect from time to time, *pro rata*, as the works reach different stages. When the credit of the guarantors is good, there will be found capitalists who can afford to wait for a considerable time for a return; and there are also to be found contractors of sufficient experience and reputation to induce capitalists to embark their money in enterprises whose success depends entirely on the fulfilment by the contractors of their engagements. This is generally facilitated when the contractors themselves share in the enterprise as capitalists, and thus afford the best proof of their confidence in the enterprise and in their own capabilities. But the willingness of capitalists or contractors to wait for a return depends entirely on the margin of estimated profit.

Negotiable bonds.

Precision in terms necessary.

Great care is necessary in expressing the exact terms of a guarantee, so as really to include all that it is supposed to cover. As an example, a trustworthy Government may give an absolute guarantee of

Fallacious guarantees.

a certain rate of interest on a specified amount of capital which is required for a new railway, and the transaction appears a safe one. But possibly there is the reasonable stipulation that the concessionnaires shall not only make the line but work it, and if the traffic prove so small as not to pay working expenses, some of the guaranteed interest may have to be expended in making up the deficiency. The Government may decline to pay this deficiency. Thus, for a line estimated to cost a million sterling, the Government may guarantee, and, if needed, pay 7 per cent. per annum on bonds to this amount, *i.e.* £70,000, all the net revenue up to this point going to reduce the amount, and all beyond it being shared by the Government and the railway company. The Government pays the interest as agreed, and their obligation ends. But there may not only be no net revenue, but the receipts may not pay working expenses. A sparsely-peopled country, a small traffic, or rates of freight which are two low, but which may have been made a condition of the concession, will afford reasons for this. The above is an additional reason why concessionnaires should investigate the probabilities of profit, even if there be a guarantee.

Guarantees inexpedient.

The principle of assisting or encouraging works of utility by guaranteeing a revenue or interest on capital, is one which is often carried too far. Indeed, in any but new or undeveloped countries it may be laid down as a rule generally acknowledged that it is not in the true interests of the community to give guarantees at all, and in the many cases where Government guarantees have been necessary to induce capitalists to construct public works, such a method should be abandoned as soon as possible. If in any country or in regard to any class of works, the system has been apparently established, capitalists will continue to depend on it. But when once the earlier enterprises of a kind so encouraged have been sufficiently developed to prove whether they are, or are likely to be, remunerative, one of two conclusions is generally obtained: either that the works will be in themselves remunerative, or that they will not. In the former case, capitalists will be found to venture, and in the latter the Government of the country should carry out the undertakings they may deem necessary directly with public money.

India an example.

See page 15, also IRRIGATION.

India affords examples of both kinds in her irrigation and railway works. The application of private capital to irrigation, whether with or without guarantees, has in very many cases proved a failure, but as in some districts profitable results appear probable, it can hardly be doubted that private capital would be directed towards the most promising localities, even if guarantees, so long considered necessary, were refused; while in cases too speculative for the private capitalist, but considered expedient by the Government, the works ought to be carried out directly with public money. In the case of railways, though a revenue more than enough in itself to pay interest on capital has on some of the lines been obtained, and nearly enough on others, the prospects of dividend do not keep pace with the extensions deemed necessary by the Government; and the good credit which made guarantees so valuable has been applied directly to the borrowing of money for State railways. But while the money for public works may thus generally be obtained by loans on better terms than by guarantees, the construction of the works is almost always better left to private contractors.

Guaranteed railways in India.

Even where there are fair prospects of success, Governments or communities will in vain invite capitalists to provide money for works of utility, unless they can assure to the investors absolute security by law, and reasonable facilities for the carrying out of their projects.

Concessions.

Having now enumerated some of the different kinds of concessions, it may be laid down as a general principle with regard to them all, that the greater the privileges granted, the more onerous will be the payments, services, or conditions demanded in return. In granting permission to execute works, accompanied by facilities, immunities, monopoly, subsidy, or guarantee, the authority which concedes does so in consideration of work to be done, services to be rendered, or payments to be made; and, in the interests of the public, makes as good a bargain as possible. Sometimes the authorities who grant valuable privileges may require a fixed annual rent. In other cases—especially where the conceding party is greatly in want of money—the annual rent or expected share of profit is capitalised, and the sum thus arrived at is demanded in advance from the concessionnaires. In others, a Government grants privileges for which it requires a payment in kind, in other words, it stipulates for a part of the results which the enterprise in question is to furnish. Thus, in the case of a railway, the right of free passage for troops may be demanded; with a telegraph line, the reservation of a wire or of priority for Government messages; with a new harbour, the right of Government vessels to share in the use without contributing to the tolls. Another system occasionally adopted is to demand in payment for a

Obligations in return.

Rent demanded.

Rent capitalised.

Payment in kind.

concession or monopoly, money for the establishment or maintenance of charitable institutions. An endowment is in this way frequently obtained for hospitals, orphanages, and schools, which the Government would not venture or choose to maintain directly out of the public funds.

Endowments.

With regard to the construction of works, a standard of quality may be set up, to which the concessionnaires must conform. This standard is generally in the nature of a specification which prescribes the extent and solidity of the works, the quality of the materials, a time for completion, and the results that are to be attained. Sometimes the result only is described, and the concessionnaires are left free to construct the works as they please. When the concession is in the nature of a contract for works for which the contractor is to be paid on completion, or after a limited term of maintenance, the transaction is at an end when this is accomplished. But when anything like a monopoly is granted, and the concessionnaires are to obtain a revenue by tolls or dues from the work itself, it is a reasonable condition that the service shall be efficiently maintained. Thus, in gas or water works, it is stipulated that gas or water sufficient in quantity and quality shall be provided at all times during the term of the concession; in a railway or tramway concession, that a sufficient service shall be maintained. The service required is generally defined both in regard to quality and quantity, and it is usual to make the latter depend upon the varying wants of the community, so that if the population increase, or traffic grow larger, the service shall be accordingly extended.

Quality of works.

Maintenance of service.

See Gas-Works *and* Water-Works.

Where dues or tolls are to be levied, their maximum scale or rate is generally set forth in the concession, and great care is necessary on the part of the concessionnaires to see that the scale of charges permitted is sufficient to be remunerative. In some cases the concessionnaires are left free to charge what they think proper, it being considered that excessive rates will be at once checked by the diminished demand and reduced profits which will follow. In cases where the concessionnaires are providing something quite new, such as a gasworks or a railway, the use of which is optional, and towards which the municipal or other authorities have not contributed, this latitude may be conceded, but where a monopoly of supplying some indispensable want, such as water, has been granted, and if, moreover, this has resulted in the stopping of previous sources of supply, the case is different. But it is generally as much

Levying of tolls.

Excessive rates not allowed.

the interest of the concessionnaires as of the public, that rates shall be defined, and in many new undertakings, rates can be agreed upon which will offer accommodation or service to the public on much more favourable terms than those which have been charged for the services which are being replaced; and at the same time afford a fair margin of profit to the concessionnaires. As measures and values are differently stated in different countries, and as in some there is a depreciated currency, it is obviously necessary that these matters should be clearly defined. Indeed, the various considerations which have been already referred to as determining the soundness of a new undertaking may be summed up in this, that it shall be profitable to both sides.

Equitable terms.

Mutual profit.

A concessionnaire or contractor who has undertaken to perform certain works, stands, so long as the engagement lasts, in the way of any one else undertaking them, and a failure—whether from unwillingness or inability—to complete, generally involves a loss of time before the enterprise can be again started. He is, therefore, generally required to give some guarantee for the due fulfilment of his engagements. Sureties or bondsmen are sometimes required, who bind themselves to forfeit the amount of damage suffered up to the amount of their bond if the contractor fails to proceed. The guarantee is in foreign countries more often imposed in the shape of "caution money," which the concessionnaire has to deposit as evidence of his intention, and pledge of his ability, to carry out his engagements. If he fail to commence within a stipulated time, the caution money is forfeited, and is supposed, in some measure, to compensate those who retain it for the trouble, risk, and delay involved in making a bargain with a second contractor. In the case of a monopoly or a concession, the exaction of caution money bars the way to those who—either from insufficient means or want of experience—are incompetent to carry out the work. A similar precaution is included by the English Legislature in Private Bills for railways. A promoter often negotiates the terms of a concession in the hope of transferring it to capitalists with the necessary means, and, in the desire to have the disposal of the concession firmly in his own hands, will sometimes go the length of depositing the caution money. Should any question arise as to the value of the concession, his position will then be one of considerable risk. Or if the works must be commenced by a certain date, he may find it

Sureties.

Caution money.

See page 5.

impossible to meet with capitalists to take it off his hands; in either of which cases, instead of obtaining a profit by the transfer of the concession, he may, in order to save the forfeiture of the entire deposit, have to pay a substitute to take the concession from him.

Risk of forfeiture.

Whoever grants the concession generally insists upon holding the caution money, but if the concessionnaire doubts the stability or fairness of the holder, it will be prudent to require that the deposit be in neutral hands. In the case of a Government, the deposit is often made in Government Stock; but whatever the security the concessionnaire is generally allowed to draw the dividend or interest on the amount during the period it is held. Sometimes it is stipulated that the caution money shall remain till the undertaking is completed, and that it shall furnish interest on the capital during construction. In other cases the caution money is retained only till the works are so advanced as to have sufficiently committed the concessionnaire to proceed. When once a concessionnaire or contractor has incurred considerable preliminary expense—as, for instance, by providing plant and purchasing material—the due completion of the works is generally sufficiently insured by the retention of part of the contract price. To hold back the caution money, as well as to retain this part of the price, is a heavy tax on the contractor, and is in many cases not in the true interests of the employer, because if more be thus withheld than is necessary, the competition is limited to the large capitalists who can afford to wait for repayment, and who generally recoup themselves by high prices. Of course when the proportion of the contract price which is retained is made small because the caution money also still remains as a security, then, whatever it may be designated, this caution money is really merged in the retention money, and the two must be considered together and weighed as one total.

Caution-money, how held.

Retention.

Fines or penalties for non-completion within a stipulated time are often specified in a concession, and under certain circumstances the concession becomes liable to forfeiture.

Fines and penalties.

It is often stipulated in a concession that profits beyond a certain amount shall be shared by the public, either directly, by the concessionnaires paying over all or part of the revenue after a certain point is reached, or by their reducing the rates or tolls charged. This is especially the case where a revenue or rate of interest has been absolutely guaranteed by the conceding parties, who by such a stipulation that the profits shall be shared, may hope to get back again,

Profits shared by guarantors.

when the undertaking is developed, what they paid in its earlier stages. The railways in India may be cited as an example; the Indian Government, which guarantees 5 per cent. on the capital sunk, dividing equally with the shareholders any excess beyond 5 per cent. which may be earned.

Right of pre-emption.

In other cases the right of pre-emption is often made a condition of granting a concession. The conceding authorities reserve the right (to be exercised or not as they elect) of buying up the undertaking at a certain time, and this may be done in various ways. Sometimes a specific price is named; sometimes it is the amount of share capital at par or with a bonus; sometimes at the average price of the shares during the preceding three years; in other cases the price is to be so many years' purchase of the average revenue for a specified number of years preceding the purchase. Many of the English railways are subject to this last condition, but the option must be exercised within a certain time. In some countries the railways are at a certain date to become the property of the State without any payment whatever. This is the case in France, where the period is eighty years. In Russia also, where many of the principal railways are guaranteed by the State, the property reverts to the Government after a term of years, and advantage has been taken of the willingness which has been evinced to construct railways to shorten the term for railways constructed after a certain date. In all undertakings, of whatever character, the concession, if subject to such a condition, has the nature of a lease, and it is obvious that before a net revenue can be legitimately divided as interest, a portion of each year's profits must be set apart as a sinking fund to repay the capital invested.

Terms of pre-emption.

Sinking fund necessary.

CHAPTER III.

CONCESSIONS CONTINUED. THEIR CONSIDERATION BY CAPITALISTS AND CONTRACTORS.

CAUSES OF FAILURE.

THE general information which is necessary to the proper consideration of a scheme, the different kinds of concessions which may be granted, and the service demanded from the concessionnaires, have been described in the preceding chapter. The peculiar details of any particular scheme will be described in its own place in succeeding chapters. It now remains to be seen how proposals are likely to be viewed by capitalists, investors, and contractors, whose aid is sought to carry them out, and what are the objections which may be raised.

Contractors for foreign works.

The kind of persons to whom an enterprise should be submitted must depend upon the nature of the enterprise and the terms upon which it is to be offered. The majority of English contractors will not undertake contracts in a foreign country, and, indeed, for the successful carrying out of this class of undertakings, special qualities of mind are needed, such as a capacity for organisation, foresight in arranging the different stages in the work, a freedom from prejudice against what is novel, a power of adaptation to new circumstances, and abundant perseverance. There are, however, contractors who undertake work abroad as well as at home, and others who, having acquired special experience in the conduct of such works, confine themselves entirely to foreign contracts. The number of capable English contractors willing to undertake engineering works abroad is, nevertheless, limited, even where there is no reasonable doubt as to the security of the stipulated payments.

A contractor for foreign works may be considered more enterprising or more speculative than the contractor who works only at home; but the two have the same aim—the earning of money by contracts. To attain his purpose the contractor for foreign works has often to assist in the raising of money and in the financial arrangements generally; but he does so only as a means to the end, that end being ultimate remuneration in money. There are various reasons why the contractor is so often made the medium of financial negotiations. An assurance is given to the capitalist—which his own knowledge does not afford—of the feasibility of a project when it reaches him through the hands of the contractor; for although the capitalist will form his own opinion as to the ultimate profit of the speculation, yet the contractor, if he knows his business, will be qualified to decide whether the contemplated expenditure will be sufficient for the works; and, indeed, without passing beyond his own proper business, he may be willing to emphasise his opinion by taking the responsibility of completing the works for a specified sum of money. It is obvious that the capitalist will be the more ready to listen to proposals involving an investment of money, when this important condition is assured, thus leaving only the investigation as to profit. A contractor can often effect a sale of shares or transfer of securities where a promoter could not, because the nature of the undertaking may be such that the securities or shares acquire value only as certain works are completed, and on this point a contractor who is incurring personal liabilities can give satisfactory assurances which from a promoter might possess little value. And if the contractor's own profit depend on his carrying out his contract for the price named, his undertaking to do so must necessarily have weight. Capitalists often prefer to be approached in this way, and do not in the majority of cases, until this preliminary stage of estimated cost is passed, care to investigate schemes which are presented to them. The functions of capitalist and contractor are, however, often combined, as the demand for engineering works and the profits that have been obtained in them have created for foreign works a class of capitalist-contractors who apply their money entirely to such enterprises. But while the capitalist-contractor reserves to himself the power of retaining a permanent share in the undertaking, should it prove a good one, he generally differs from the ordinary investor in desiring to get back his money as soon as the work is finished.

Contractors and capitalists.

Sale of shares by contractors.

Reference has been made to the fact that since the time when railways were first introduced, numerous cases have occurred of a contractor taking part of his payment in shares, and making large

See page 11.

Payments in shares.

See Syndicates, *page 42.*

Contractors assist in raising capital.

profits by so doing; but, on the whole, such instances have been exceptional. However, because of the examples of this kind that have occurred, and many others when the contractor has appeared to have accepted payment in shares while in fact relieved of them by previous arrangement with capitalists, there exists among those not well-informed the belief that contractors for foreign works will be disposed to take payment in shares, obligations, or something that is not money. It may thus be accepted as a rule that contractors will not take anything but money in payment, except such securities, obligations, or shares, as they can at once, or within a reasonable time, sell or transfer to others for money. Nevertheless, contractors will listen to proposals of this kind, because—knowing by experience what conditions are necessary to obtain the capitalists' aid—it may be worth their while to take trouble in assisting such negotiations if success will bring them a profitable contract; but unless the nature of the undertaking and the rate of profit are such as will, in their opinion, attract outside investors, they will rarely proceed. Even if a contractor himself aids the enterprise by providing some of the capital, he will usually limit his investment to the amount of his estimated profit. The most conspicuous examples of failure among contractors have been when they have accepted as payment for work, securities or obligations which proved unsaleable.

There are contractors who are so careful in this respect as never to meddle with finance, even to the extent described above, and who, while possessed of means sufficient even for large undertakings, use their capital only for the necessary advances of their business, working only for punctual and—as far as can be foreseen—secure money payments. When practicable it is desirable to employ contractors of this class, as they will generally be content with a less profit than those accustomed to speculative enterprises; and even where financial assistance is required, it may be possible to obtain the services of such contractors by dividing the business into two transactions, and obtaining the money in some other quarter. But where the security is at all speculative, or one which cannot be understood without special or technical knowledge, the capitalist will generally require that the whole business be placed in his hands. He will then either himself become the contractor—nominally or really—or ally himself with a contractor whom he knows and with whom he can arrange terms.

There are different classes of capitalists who provide money for engineering enterprises, and according as any scheme is speculative, so does the number of those able and willing to assist become small and the terms onerous. To lend money for such undertakings does not come within the business of a banker according to the strict English interpretation of his functions, although indirectly, as will be seen, bankers do assist. For instance, a banker will lend money for carrying on the work, on the security of a contractor's plant and property, if he deem it good enough. In other cases the contractor or concessionnaire can offer as security, shares or obligations of the undertaking in question; these, however, a banker will not value according to the probable ultimate success of the scheme—although an assurance on such a point has some weight if other matters are satisfactory—but according as the securities are marketable. It is not the business of a banker to invest his money in enterprises, however remunerative, but to lend it for short and exactly-defined periods on good and marketable security. It is for this reason that bankers prefer to employ their money in discounting good bills of exchange, which satisfy these conditions, as the period of repayment is exactly defined, and the means of enforcing it in case of default are the most peremptory the law knows. Bankers, therefore, prefer to consider any bonds, shares, or obligations deposited with them, and which are not immediately saleable, only as collateral security, and look to the names of the borrowers as expressed on a bill or promissory note as the best assurance of safety. But while most English bankers will in theory define their functions strictly as above, there are few who have not at times found themselves burdened with unsaleable securities on which they have advanced money. They have been induced perhaps by their confidence in the borrower's ability and probity, at a time possibly when money was very plentiful and the ordinary outlets for it were scarce. Bankers can also often assist enterprises indirectly, because their business brings them in contact with speculative capitalists, and they may have clients willing to entertain offers of the kind.

Loans from bankers.

Shares as security.

Bills of Exchange.

There are other capitalists—individuals, or financial societies—who go further than the banker, and lend money for longer and less exactly-defined periods on unnegotiable securities, and yet who do not care to enter directly into the risks of an enterprise. Cases of this sort arise where contractors are entitled to certain payments at a future date, or possess bonds or obligations which, though having little or no present value, as measured by any interest or income they may

Financial societies.

Speculative capitalists.

produce, will, when a certain time has elapsed, or certain contingencies have been fulfilled, become saleable. Capitalists will of course demand more than the ordinary rate of interest for advances of this sort ; and besides the interest calculated in the usual way per mensem or per annum, often require a bonus or sum of money to induce them to assist. There are, again, capitalists little known to any but those who deal with them, who go further in assisting contractors. Such capitalists desire to be assured, first that those who have to pay for the works are solvent and honest, and then that the contract price is such as will leave sufficient profit. On this second point the contractor has, by furnishing details of anticipated expenditure and receipts, to afford an opportunity for verifying his calculations. Capitalists of this sort will sometimes be content with no other security than that of the contract itself, but will generally take care to have a first charge upon all the profits, and will stipulate that they be made cognisant of all expenditure and receipts. They become, in effect, preference partners in the enterprise; but, while taking the first share of the profits, keep in the background and incur no liability or risk beyond the sums they have advanced. Capitalists will seldom assist in this way except where the contractor is able to provide some of the capital, either in money or plant, and the capitalist has the first charge on the earnings of the joint contributions. Very often the profits of a contract are so large when the works are carried out by a skilful and energetic contractor, as to allow ample profit after the capitalist has had his share ; but not unfrequently a sanguine contractor, in his eagerness to obtain the aid of a capitalist, will engage to pay so highly for it as to have little or nothing left for himself, even on what is *per se* a profitable enterprise.

Preference partners.

Syndicates.

The earlier proceedings in connection with a new undertaking are often conducted by a "Syndicate," or group of persons (thus designated by a modern adaptation of an old word), who, wishing to further one common object, combine for the purpose, but who are not, in the ordinary sense, partners. This means is adopted by persons unable or unwilling singly to provide all the necessary money, but who think it worth while to speculate to a limited amount. A syndicate is very often formed merely to provide money for preliminary expenses, and with no intention of providing capital for the undertaking. For instance, this course is adopted very often where a certain expenditure must be incurred before a company can be formed or works commenced; and the members of the syndicate thus take upon themselves the speculative risk (which it might be impossible, or improper, or illegal to incur as trustees for shareholders) of losing all the expenditure in case the undertaking fails to proceed. In such cases the syndicate may be said to take the place of a promoter. Sometimes a syndicate will even engage to provide all the capital for an enterprise, but if the members retain their interest in the undertaking, they may be more correctly designated as a company. But a syndicate which provides the capital generally does so merely to ensure the commencement of the undertaking, and even for this purpose the members often employ their credit only, rather than actual money. For instance, if £50,000 be required for some joint-stock undertaking, ten persons of established credit may guarantee to provide by themselves, or their friends, £5,000 each, in the hope and with the intention of transferring to friends or clients the proportion of shares which they have guaranteed to take. A contractor who has agreed to take payment for his work in shares, or a promoter who is interested in the formation of a company, instead of risking all by an appeal to the public for subscriptions, the failure of which might much prejudice his scheme, sometimes prefers to invite a combination of capitalists to take all or a large number of shares in the undertaking at a reduced—or what may be termed a wholesale—price before they are offered to the public at their full price. The members of the syndicate then dispose of the shares from time to time at the full price, as there appear buyers for them. This method of forming a syndicate may also be adopted with advantage when an existing undertaking requires more capital at a time when the money market is unfavourable for a public subscription. From this point of view a member of a syndicate is valuable in proportion to the number of persons whom he can influence; but as, in times of excessive speculation, investors have been often induced by those whose advice or opinion they trusted, to embark in enterprises which prove fallacious or disastrous, syndicate combinations have in such cases been greatly discredited. Fairly conducted, however, they are legitimate and convenient.

See page 21.

Capital provided by syndicates.

Syndicates discredited.

There are frequently cases in the English Colonies where profitable enterprises are hindered for want of funds, which cannot be obtained locally even where there is tangible—though not always immediately saleable—security in the shape of land and other

See page 14.

property. The circumstances may be such as to warrant the payment of interest much above that usual in England, and yet such security fails to attract English investors. But just as water will, even through indirect channels, find a level, so English capital finds its way through the medium of colonial banks and financial societies which are established in England. Such societies can successfully invite deposits at ordinary rate of interest from investors, because they can offer the security of their own subscribed capital, to which returned colonists, who know their country, largely contribute. The difference between the English and colonial rates of interest allows a considerable margin of profit to the society, colonial enterprise is encouraged, and the English investor is secured.

Colonial Banks.

Promoters' credentials.

If a promoter has a scheme thoroughly matured, and is prepared to supply the information described in the preceding and following pages, he will have little difficulty in obtaining at any rate consideration of his scheme. He may possibly be able to produce only the necessary technical and local information, and, as regards money, may be desirous of learning the kind of terms on which capitalists will assist him. If he is furnished with proper credentials and full powers to treat, and the enterprise is not of a great or exceptional kind, he will have no difficulty in obtaining offers from competent capitalists and contractors. But if the promoter has limited powers and can do no more than send home to his principals for consideration any offer he may obtain in England, he will find capitalists and contractors indisposed to commit themselves without some guarantee. Contractors are always averse to giving tenders which are to remain open for an indefinite time, and which may possibly be disclosed to competitors. An experienced contractor having made an estimate of cost, or a financier having calculated the terms upon which the enterprise may be carried through, possesses important information, which in its way is, when imparted to the promoter, as valuable to him as an engineer's design, or any other essential part of the scheme. The promoter will, therefore, have to satisfy those who have helped him that their offers will be fairly dealt with, and that, if the terms are reasonable and within the means at command, they will be accepted.

Guarantees required.

Even where the honour and good faith of the promoter are undoubted, he may not always be able to prevent unfair dealings with the offers he has transmitted when they have reached a foreign country. It is no exaggeration to say that in the thirty years ending

1877, hundreds of thousands of pounds have been expended by English contractors in making preliminary surveys, investigations, and even working-plans, which have produced for them nothing in return, but which have been eventually handed over to the use of others. It is not to be inferred from the above caution that contractors and capitalists object to competition; but it is a reasonable stipulation on their part that they be made aware of it from the commencement of the negotiations. Contractors wish also to be satisfied that their competitors shall have no unfair preference, and that their own estimates of cost shall not be obtained merely as a means of beating down in price other contractors, to whom it is intended from the commencement to offer the concession.

Unfair preference.

In some cases the promoter is unable to furnish sufficient information upon which to base an estimate of cost, and, as referred to previously, he may be asked to share in the expense of obtaining it. Even where full information is afforded, the contractor will generally require to verify it. If this involve a journey to a foreign country, and the further expenses of a survey, the contractor will sometimes stipulate for the option of taking the concession on stated terms, or for remuneration in case the business falls through. There are cases where no such stipulations are made, because the anticipated profits of the enterprise and the likelihood of success are sufficient to induce a contractor to incur considerable trouble and expense in preliminary surveys and negotiations without any guarantee. These are all matters which the promoter has to consider, and for which no general rule can be made.

Contractor's surveys.

Those who are interested in the furtherance of some new enterprise, often suffer disappointment by failing to obtain the adoption of their scheme, or that assistance in carrying it out which they seek. As to be forewarned is, to some extent, to be forearmed, it may be appropriate here to indicate some of the causes of such failure.

Schemes fail of adoption.

Promoters of new undertakings abroad are generally too sanguine concerning the aid which they may obtain from English capitalists. Having seen or heard of the apparently similar enterprises which have been so aided and carried to success, they are perhaps unaware of, or attach too little importance to, the much greater number of schemes which have been laid before capitalists, and declined. To reduce as far as possible the chances of failure, the first and most important point is to afford every information at the outset, even of what may

Promoters too sanguine.

be considered the weak points of the enterprise, because if these weak points are left to be discovered by investigation and inquiry, it is not unnatural for those who discover them to doubt the good faith of the promoter who has concealed them, and to suspect that there may be other flaws also. The promoters or others locally interested in the success of a scheme may often do much to render it acceptable to contractors and capitalists by eliminating from it many risks which they themselves may better—because of their greater local knowledge—undertake. It may of course be considered preferable that contractors should undertake all the responsibilities; but it must be remembered that there are two parties to a bargain, and that the more onerous the conditions and the greater the difficulty of measuring the risks, the less will be the number of those who will entertain them.

Flaws discovered.

See ERECTION OF BRIDGES.

An engineering enterprise, to be successful, must satisfy certain technical and economical conditions; and these demand entirely different kinds of investigation. An engineer to whom a scheme is submitted may find that it is feasible, and that as no experimental methods or extraordinary works are required, the risk will be but small; the calculations of outlay and profit may also appear to him reasonable, and he gives to the scheme the sanction of his name. Yet there may be economical reasons, which to a financier or economist, as eminent in his way as the engineer, will show the unsoundness of the undertaking. The fault is sometimes on the other side. A scheme is submitted to a financier who, uninformed on technical matters, may accept as correct the plausible but incomplete engineering details, and on such a basis may decide that the scheme will be safe and profitable; while in reality there may be some flaw—perhaps even of a rudimentary kind—which bars the way to success. Were it not that failures frequently occur for these reasons, the need for fuller investigation would appear too obvious to be mentioned.

Financial flaws.

Engineering flaws.

But even where the feasibility of a scheme, both in its technical and economic aspects, appears certain, it often fails for some secondary reason to obtain support.

Time not favourable.

The time for introducing the scheme may be unfavourable.—There occur periodically seasons of distrust in the financial world, when, owing to recent panic, failure, or other causes, almost every kind of new undertaking is looked at with suspicion. This state of things may even produce a superabundance of capital ready for investment, but which the owners may be afraid to invest, and the apparent anomaly presents itself of a plethora and a scarcity of money at the same time. It is obvious that distrust will produce this double result.

Schemes discredited

Similar schemes to the one presented may have recently failed, or, to take an extreme case, the public mind may have been prejudiced by the recent exposure of actual mis-statements or impositions in regard to them. And further, even when the scheme is a sound one, and when the capitalists before whom it is laid for consideration are able to distinguish it from others which have proved unsound, they may decline to deal with it, because if the enterprise is to be offered to the public for subscription, it is generally useless at such a time to argue against the public distrust. The fact must be accepted, and a more favourable opportunity awaited.

Scheme too large.

The undertaking may be too large.—In the case of public works of great magnitude involving a very large expenditure, and where the assistance of the public has to be obtained on a great scale, the affair demands special treatment, and if undertaken only in the manner of ordinary enterprises it may fail. The feasibility and profitable nature of the undertaking may have to be explained with exceptional clearness to the public mind, the condition of the money market may have to be closely studied, and special legislative guarantees may be found necessary. Where the enterprise is novel and speculative as well as large, it seldom can be successfully started till the mind of the public has been educated to receive it, and this is sometimes the work of years. The Suez Canal and the Tunnel under the English Channel are extreme cases of this kind. It will be found that those whose usual business is to negotiate undertakings of an ordinary kind will hesitate to engage in these special ones, which promise no practicable or profitable results to themselves within a reasonable time, even though they may be convinced of the ultimate success of the scheme.

Scheme too small.

The undertaking may be too small.—There are unavoidable expenses incurred in raising money from the public for a new undertaking, and these are generally much greater in proportion for a small than for a large amount, and they will sometimes entirely swamp the enterprise. Small undertakings are most successful when carried out by a limited number of capitalists, who subscribe the necessary funds by private arrangement without any expenditure for promotion, and who thus insure that all the capital will be applied, without deduction, to the real end in view. As in the preliminaries, so also in the carrying out of the work, small undertakings in foreign countries cannot be profitably managed from a distance. In every foreign enterprise, whatever be its extent, if it is carried through by English capitalists or contractors, certain organisation and management are necessary. **Expenses of management.** The trouble, expenses, and responsibilities attendant on these may, in the case of small undertakings, be so great in proportion to the expected profit as to deter from the enterprise those who but for this would engage in it. Capitalists and contractors who usually undertake such works cannot or will not set in motion for small affairs the machinery necessary to proper management. If, for instance, works costing £10,000 or £20,000 are wanted in a distant country, there will sometimes be far more difficulty in getting capitalists or *See* BRIDGES. contractors to undertake them, than if the cost were five, ten, or even twenty times as large. This objection will have weight in proportion to the remoteness of the country and the want of security there. Cases of this sort are eminently those for local enterprise. Engineering aid may be obtained in England, machinery and plant purchased, and experienced superintendents engaged at salaries to assist, but it is not easy to find anyone in England willing to take all the responsibility up to completion. Sometimes advantage may be taken of the presence, in the distant country, of English contractors, who happen to be engaged there in other works of greater magnitude, and who may be willing to use their staff or plant for the smaller enterprise. Sometimes, also, English contractors accustomed to small affairs, and who know something of the country, may undertake the works, because, by giving their undivided personal attention to them, they may make a good profit, when, if loaded with the expenses usually attending deputed management, the enterprise might be unremunerative. Promoters of small undertakings may sometimes be fortunate enough to find contractors in England who have some of their staff disengaged, and who, to retain the services of experienced men, may be willing to employ them temporarily on smaller works. There are gradually growing up in the English Colonies and other countries which have depended on **Local contractors.** English aid, local contractors, who, as they accumulate profits in small undertakings, will in time be able to undertake large works.

Some of those who are most likely to achieve this position have been agents or sub-contractors on works undertaken from England.

The estimated profit may be too small.—There is no standard by which the sufficiency of the return offered by any enterprise can be measured. The rate of profit which will induce capitalists or contractors to undertake works, increases with the risks, the trouble, and the distance from home. According as the difficulties appear great, so will the number of persons willing as well as able to contract become small, and those who are willing naturally demand terms advantageous to themselves. If the profits gained in previous contracts of a similar character are cited as a reason for lower terms, due allowance must be made for differences, however slight, which attend the new enterprise, and to the fact that risks which have been avoided or overcome in the one case, have yet to be encountered in the other. It may be that the amount of profit gained in a previous enterprise is felt to be insufficient, and in itself is an argument against, instead of for, undertaking another on the same terms. There are generally differences of opinion between buyers and sellers, and after every argument has been used, it of course remains entirely at the discretion of the contractor to adhere to his own terms. The matter is then finally determined by the ordinary rules of supply and demand, and if competition be limited by the nature of the undertaking, or for other reasons, the contractor will naturally be somewhat guided by the necessities of the buyer, and will hardly forego voluntarily the maximum price which he feels the buyer is willing to pay. Not only the price but also the terms and conditions are determined by these same considerations.

Profits too small.

Profits of previous ventures compared.

The profits may be too long postponed.—Even where the profit which is ultimately to be gained appears sufficient, too long a postponement of it may disincline capitalists or contractors from an enterprise. Although the estimate of cost may have included interest on capital during the period of construction, or of waiting, those who engage in public works like to get the principal money itself back again as soon as possible, so as to use it again. Even if the necessary capital is to be raised by appealing to the public for subscriptions, the postponement will have the same deterring effect, and will reduce the number of contributors.

Postponed profits.

See also RETENTION *pages 36 and 72.*

There are, of course, capitalists who will wait a considerable time if the profit ultimately to be gained appear sufficient and well enough secured; but there are others—and these the majority—whose assistance can be obtained only in those enterprises where there will be a return within a reasonable time. If, for instance, the capital be held in shares, whatever may be the nominal rights of transfer, shares on which the profit is merely prospective are not always easily saleable. Even though there be risk of great fluctuations in price, speculative investors will often prefer what they can always sell at some price to that for which it is difficult to find any market. As pledges or security, bankers always prefer such saleable shares. It need hardly be mentioned that of only a small proportion of the undertakings in which capital is invested, are the shares quoted on the Stock Exchange, and saleable at all times.

Saleable shares preferred.

See page 41.

The terms or the advantages of the concession may be too vague or speculative.—On this rock of difficulty a large proportion of schemes proposed by sanguine promoters split at an early stage. Indeed, it is astonishing how persons who have any claim to business capacity can expect consideration for some of the immature, vague, and even absurd schemes which they bring forward. Some explanation may perhaps be found in the fact that the scheme in question is one entirely outside their own experience; and promoters who may be shrewd enough in their own proper business may be ignorant of the rudimentary objections which are fatal to their new scheme. Examples of this vagueness are often furnished by schemes for the purchase of a new patent, or other speculative monopoly. Large gains have resulted from such, but as not one patent in twenty repays the inventor, the advantages offered must be very apparent, or at least capable of very easy proof, and the profits must be considerable, to induce capitalists to rely upon them.

Vague concessions.

Sometimes the vagueness lies in the definition of the payments. The following may be given as an instance: A promoter will offer some new enterprise to a contractor or capitalist, who is to accept, in return for his aid, remuneration, all or in part, in shares, debentures, or obligations. Now, it is possible that the scheme may be so sound that such remuneration, if properly arranged, may be sufficient. But it is obvious that the value of shares or debentures depends upon various considerations, besides the mere nature of the enterprise. The jurisdiction under which the undertaking is to be carried on; the amount of capital to be raised; the proportion the

Payments vaguely defined.

See page 22.

capital will bear to the cost and profits of the undertaking; the proportionate amount of shares and debentures; the priority, if any, of one kind of share over another, or of debentures over both; the nature of the guarantees; the names and reputation of the person who are to manage the affair; information on these and a variety of other points is essential to a proper assessment of value. As has been referred to already, it is primarily the duty of the promoter to arrange these matters. If he does not, he should acknowledge his position at the outset, and at any rate be prepared with such information as will, if the enterprise is a good one, enable those who have experience in such matters to prepare a complete scheme But too often the promoter professes to have a very complete scheme ready; and it is only by an exhaustive series of questions that its inchoate condition is discovered, when the prospects of the enterprise are discredited accordingly.

See page 21.

Inchoate schemes.

Insecurity.—Apart altogether from the ordinary chances of profit or loss, which according to its nature accompany every enterprise, an earlier question of security arises. There are countries—unfortunately not unknown to British enterprise—where all property is insecure. Liability to war or civil commotion, during which works may be interrupted or property destroyed; the despotic nature of governments, or sudden changes of rulers, are causes of insecurity. One set of ministers may repudiate the acts and obligations of their predecessors; obligations which were originally promised in gold may be paid in paper or depreciated currency. A natural want of honesty; a low moral tone in the people; corruption in officials or tribunals; jealousy of foreign interference, are other causes. Taxes from which an undertaking has been directly, or by implication exempted, may be inflicted; and *ex post facto* legislation, nominally general in its application, may be aimed specially at the foreign capital, which has ventured within its power. Sometimes, through poverty or greed, or sheer dishonesty, guarantees are repudiated; and though stern necessity is often pleaded as an excuse for such injustice, the injury is none the less. Even where a supposed security has been given as by liens on property, or special hypothecation of revenues or taxes, it may prove impossible from weakness or partiality in the law to foreclose, and the capitalist may find himself without remedy. Sometimes, while no direct repudiation may be attempted, the conditions of a concession, the meaning of an agreement, or a

Insecurity.

Repudiation.

Corrupt officials.

Fallacious securities.

statement of accounts may be disputed, and advantage be taken of the dispute to refuse payments which are due. Many such cases **Disputed accounts.** have occurred in countries which would not venture to hold back the interest on a public loan, and it is for this reason that public loans, which pledge the credit of a country unconditionally, are *See page 29.* more favourably received by capitalists than conditional guarantees. Countries where wrongs of this kind are perpetrated of course lose their credit, and have to pay dearly for it in the future. Capitalists are sensitive of anything savouring, however remotely, of **Confiscation.** confiscation, and although the temptation of high gains may induce speculative investors, resting on fresh assurances, to enter into new enterprises, the sources from which capital can be obtained are for such countries greatly narrowed, and the difficulties in the way of promoters are immensely increased. Even where no previous repudiation has damaged the credit of a country, and there is no reason for doubting the good faith of its rulers, intending investors should take pains to ascertain the resources available, and to see that the obligations incurred are really within the means and power of the people to fulfil.

Extravagant demands.—Reference has been made to the price or *See page 22.* consideration which has sometimes to be paid for a concession. Foreign enterprises are in the majority of cases introduced to **Promoters' claims.** English capitalists by promoters who seek a profit from the transaction; and behind these promoters may be others also who have to be conciliated or paid. The skill and trouble which have been bestowed upon a scheme in its earlier stages may have been as necessary and as legitimate as the actual carrying out of the works; and payment for these services may be claimed with equal fairness. So also, as in other business transactions, commissions may have to be paid to those who aid in bringing together the various parties to the transaction, or who, by their experience in such matters, know what to do or avoid in steering the undertaking to maturity and success. More than this, the undertaking may be of such a remunerative nature as to entitle those who dispose of it to a distinct **Arbitrary prices** and considerable profit. It is obvious that no rule can be laid down on such a matter. But as in regard to new enterprises there is often no fixed standard by which to measure value, and as the promoters may have, in the first instance, to name an arbitrary price, there is often a not unnatural tendency to take advantage of such a position, and to demand too much. Where the interests of the promoters lie in this direction, it is not difficult for them to prove, at any rate to their own satisfaction, that the price and terms they demand are well within what the profits of the enterprise will afford, and are altogether justified by the merits of the case. A seller naming his own price often has these views.

Extravagant demands.

In undertakings of a speculative character, promoters are sometimes to be found who will provide the funds for preliminary expenses, but who will require, in consideration of the risk of losing all their advances in the event of failure, very high payment in the event of success. For instance, in the case of an undertaking for which a capital of £100,000 is invited, £1,000 may be needed for preliminary expenses; but the secondary promoter who provides this may stipulate that he be paid £20,000 in case the capital is raised. This is quite within the mark of what has been demanded and obtained by promoters of companies. It is of course just possible that an enterprise may be of such a nature as to bear so heavy a charge, and still be sufficiently remunerative. These very profitable undertakings are, however, rare; and where an extravagant demand is made for "promotion" only—that is, independently of purchase-money for absolute value transferred—it would, in the great majority of cases, be only fair in those who are aware of this demand to abandon the enterprise altogether. The smaller the undertaking, the less able will it be to bear a burden of this kind. Exorbitant demands, however, are frequently and fortunately a bar to further progress; and the promoter, in asking too much, fails to obtain anything.

See page 24.

Heavy charges.

It is evident that if an undue load of charges be put upon an enterprise, the effect must, sooner or later, be disastrous to those who embark capital in it. Examples may be seen in all directions of railways and other public works, with moderate working expenses, with a net revenue amply sufficient to pay remunerative interest on the real cost of the undertaking, and yet which afford little or no dividend to the proprietors. It has been discovered too late that so much money was squandered in preliminary expenses, in extravagant outlay, heavy commissions or corruption, that the nominal capital is far in excess of what would have been necessary under honest and capable management. To meet these charges the capital has been so extended, or the shares so "watered," that the revenue, when divided, will only pay a very small rate of interest; or preference obligations have been incurred to such an extent that no

Excessive capital.

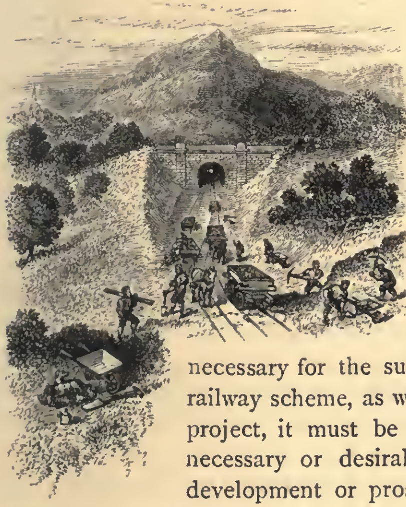
Watered shares.

dividend at all is left when the prior claims have been met. Capitalists are not blind to these contingencies, of which there is much past experience to warn them; and although occasional success in evading scrutiny may encourage promoters in extravagant demands, the majority of schemes so treated deservedly fail. Where, however promoters have a sincere and well-founded belief in the value of an enterprise, they can obtain an ample share of profit, and, at the same time, give proof of good faith by deferring their own claims till those of the other investors have been met. Arrangements of this kind have been already referred to.

Incapable agents. Extortionate or incapable agents are a frequent cause of failure. In the case of foreign enterprises the extravagant demands of the kind above referred to proceed sometimes also from the English agent entrusted with the negotiations, and the load put upon an enterprise by the original promoters may be thus unwarrantably increased. Agents who have obtained an evil reputation by past transactions, and whose names are associated with dishonest schemes, discredit every fresh enterprise they touch, and they should be avoided accordingly.

CHAPTER IV.

RAILWAYS.



THE amount of British capital expended in the construction of railways equals or exceeds that invested in all other modern public works put together; and there are engineers, capitalists, and contractors who confine themselves almost entirely to this one kind of enterprise. But in considering the conditions necessary for the successful carrying out of a new railway scheme, as well as of any other engineering project, it must be borne in mind that, however necessary or desirable the work may be to the development or prosperity of a country, capitalists whose aid is invited will look at the enterprise solely from an economical point of view. If a railway is likely to produce enough revenue, directly it is opened, to pay a fair interest on its cost, this likelihood affords a *primâ facie* plea for obtaining the money for its construction. Subject to its feasibility, and the other general conditions alluded to in the preceding chapters, it is obvious that the probability of an immediately remunerative return is the essential preliminary question to be settled; and the burden of proof of this lies on the promoters. Still, if this question cannot be answered satisfactorily, it does not follow that the railway should not be made. There may be so many secondary, or indirect, advantages to be gained that the inhabitants, either directly or through their Government, may give

Conditions of success.

Interest on cost.

Secondary advantages.

such contributions, subsidies, or guarantees as will compensate for the deficiency, and make the enterprise a safe one for the outside capitalist. Various arrangements of this kind have been already alluded to.

See pages 24 to 33.

Calculations of profit.

In calculating the probable profits of a railway, there are three principal factors in the estimate :—

I. The Cost of the Railway.
II. The Expenses of Working and Maintenance.
III. The Revenue.

Calculation of cost.

I. *The Cost of the Railway.*—The calculation of cost depends on the special nature of each case. The primary expenditure is that for land, in the price of which there is the widest divergence, it being one compensating feature in new, or poor countries that land is there easily obtained. In England, the average rate of interest paid by railway undertakings is much less than it would be if the land had been obtained on equitable terms. But legislation with regard to railways has been so conducted that not only have excessive prices been demanded and obtained, but extravagant compensation has been allowed, where, instead of the injuries pleaded, great advantages have been certain to accrue from the railway. The amount of land required depends, first, on whether a single or double line is required; secondly, on the width of gauge; and, thirdly, on the nature of the works. As almost everything connected with a railway—land, works, and rolling stock—is to some extent determined by the gauge, which may almost be termed the key-note of the project, the subject demands careful consideration.

Cost of land.
See also pages 3, 16, 25.

Width of gauge.

The gauge of 4 ft. 8½ in., which was adopted first on English railways, and which, as the "standard gauge," now generally prevails in Europe, was that of the existing vehicles on common roads; and, although the precise dimensions were accidental, being those of the colliery tramways which were the immediate precursors of railways, it is useful to remember that the ordinary custom in regard to the width of carts and carriages was the outcome of long experience, and that such vehicles had been found wide enough, but not too wide, for the safe and convenient conveyance of passengers and goods. And, after many years' experience of railways, both wider and narrower than the original standard gauge, it is found that while a wider gauge is unnecessary, a narrower one—though sufficient for railways of par-

Standard gauge.

Gauge of ordinary vehicles.

ticular kinds, such as will presently be described—does not fulfil all the conditions necessary for an important line.

For many years after the establishment of railways in England the standard gauge of 4 ft. 8½ in. was accepted almost without question everywhere; and, where any difference was made, it was in the direction of a wider gauge. But the great demand for railways and their high cost, have induced a closer investigation of the subject; and, by the aid of fuller experience, the long-existing uniformity of ideas has been destroyed. It is not the place here to weigh all the comparative merits of narrow and wide gauges, heavy and light railways. This has been done almost exhaustively during the five years ending 1877, and the discussions have elicited most important facts, which are available for reference. For the present purpose, the following may be stated as axioms agreed to by the great majority of railway engineers:—

Wide gauges *versus* narrow gauges.

(*a*) There are no peculiar merits in the standard 4 ft. 8½ in. gauge which, apart from the advantages of uniformity, make those exact dimensions the best for railways.

Break of gauge.

(*b*) The inconveniences and expense attending the break of gauge are so great, that without special and weighty reasons, no new gauge should be introduced into a district or country where railways of another gauge may be expected to come in contact.

Standard gauge preferable.

(*c*) Where the traffic of a country is great or is likely to become so, and where the necessary money can be obtained without too great a burden on the community, it is better to avoid any gauge much less than the standard gauge; and, as there are several minor advantages in having railway stock and appliances similar to those in other countries, the standard gauge should be preferred. The conveyance of large guns, large boilers, thrashing-machines, and similar bulky articles, is not easily accomplished on a narrow-gauge railway; and if, to maintain the same loading gauge, wide and lofty trucks are built on a narrow wheel-base, the centre of gravity in the vehicles would almost necessarily be high, and they would not run safely. The same width of land, tunnels, and bridges as for the standard gauge would also be required. Moreover, so long as locomotives are wanted of the strength and speed now adopted on the principal lines, nothing much less than the standard gauge will afford sufficient strength, and at the same time allow convenient access to all the working parts.

Reasons against narrow gauge.

See LOCOMOTIVES *in Part II.*

(*d*) Narrow-gauge lines of from 2 ft. to 3 ft. 6 in. are sufficient for

Narrow gauges. very considerable traffic; those not less than 2 ft. 6 in. gauge being sufficient for a maximum speed of 20 miles per hour; those of 3 ft. for 25 miles per hour; and those of 3 ft. 6 in. for 35 miles per hour, with ease and safety.

Cheapness obtained. (*e*) The saving in land by the use of narrow gauges is inconsiderable; but the saving in works and rolling stock is considerable, say 20 per cent. and upwards, according to the weight of the locomotives and the corresponding strength of the permanent way.

Cost of railways. *See in Part II.,* RAILWAY EQUIPMENT *and* FLUCTUATIONS IN PRICES.

As already stated, there is no fixed rule for the cost of railways. A single line of the standard (4ft. 8½in.) gauge will, in a flat country, with embankments and cuttings averaging 3 ft., if of light construction, with rails of 55 lbs. to the yard, and ballast 15 in. to 18 in. deep, cost from £4,500 to £5,500 per mile; in the same class of country, if of heavy construction, say with rails of 75 lbs. per yard, and ballast 24 in. deep, the cost will range from £5,500 to £7,000 per mile. These prices are for lines in countries where—although the works and equipment are strong and effective,—the strict rules which the Board of Trade enforces in England in regard to stations, signals, &c. are not in force. Moreover, in new countries there are not so many existing roads, railways and canals to be crossed as in England; level crossings are often allowed instead of bridges, and the engineer, having few vested interests to conciliate, can choose the best routes and levels. The prices also are exclusive of the cost of land, but include that of the stations and permanent works, but not of rolling stock. The last depends, of course, on the kind and amount of traffic, which have no fixed relation to the length of the line; but £700 to £1,000 per mile will include the sum which has been found necessary on most of the single lines built in foreign countries. The above amounts do not cover extraordinary works of any kind. When railways cross hilly country, or where the cuttings and tunnels are numerous or of heavy material, or where expensive long-span bridges are required, the cost rapidly increases. The cost of tunnels for a single line of standard gauge may be stated as £25 per lineal yard and upwards, depending on the nature of the material to be excavated, on the masonry or other new work to be performed, and on other circumstances. From £40 to £90 per lineal yard are limits of cost wide enough to include the great majority of double-line tunnels; but in exceptional cases these rates of expenditure have been greatly exceeded. The Kilsby

English rules not enforced abroad.

Cost of rolling-stock. *See also in Part II.*

Extraordinary works.

Cost of tunnels.

tunnel, 1⅓ mile long, with a double line of standard gauge, on the London and North Western Railway, which had to pierce a stratum of quicksand, and in which continuous pumping on a great scale was necessary, cost £125 per yard, and even this enormous sum has in a few cases been exceeded.

Expensive tunnels.

Standard gauge involves heavy works.

Radius of curves.

See in Part II., Locomotives *and* Rolling-Stock.

Gradients.

See also Tramways

Steep gradients.

In a hilly or undulating country the construction of a standard-gauge railway with moderate gradients generally involves considerable expense for embankments, cuttings, and tunnels, which would in many such cases be avoided if steep gradients or sharp curves could be permitted. But the width of gauge prevents sharp curves, and on the main lines of the principal English railways curves of less than 1,650 ft. (25 chains) are considered unsafe for heavy trains running at high speed, and even on branch lines it is always considered desirable to avoid any less radius than 1,320 ft. Where there is a less radius (and there are on some main lines sharp curves of 700 to 1,200 ft.) a reduced speed becomes necessary, although the modern improvements in bogie-frames for engines and rolling-stock ensure smoother running than formerly. Steep gradients add so greatly to the locomotive power required, that even at an increased first cost engineers endeavour to avoid them. Generally speaking, the gradients on English main lines are seldom steeper than 1 in 100, and several of the more important railways have sections of 100 miles with no gradients steeper than 1 in 200. Many even of the best lines, however, have a few exceptional gradients of 1 in 90 to 1 in 70, while in some rare cases both passenger and goods trains are drawn by locomotive power up 1 in 37. There are also mineral railways where inclines as steep as 1 in 19 are overcome by locomotives pushing the trains, and 1 in 15 may be taken as the absolute limit for locomotives dependent in the usual way for their tractive force on the adhesion to the rails. For gradients steeper than 1 in 15 special kinds of locomotives, fixed engines, or other exceptional apparatus become necessary.

Cost of double lines.

Even leaving out of question the enhancement of cost which has so often in England resulted from Parliamentary contests, extravagant compensations and inequitable payments, some single-line railways have, from the nature of the works alone, cost over £20,000 per mile. The cost of a double line will add approximately from 50 to 75 per cent. to the rates per mile above stated; but as the advantages afforded by a double line over a single line consist in the convenience, regularity, and safety of working, as

Equipment of double line.

well as in the increased capacity for traffic; and as the cost of equipment—station fittings and rolling-stock—depends mainly on the traffic, the additional cost of equipment for a double line does not follow in the same proportion, and unless the traffic be much increased, from 10 to 30 per cent. would cover it. But as a double line worked to its full extent will carry much more than double the traffic of a single line, the expense of rolling-stock may in such a case also be more than doubled with profitable results.

Quantity of land required.

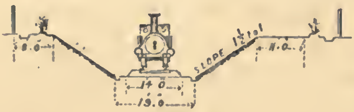
See diagrams below.

Depends on slopes.

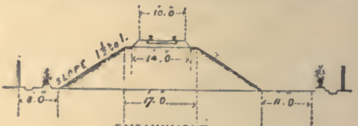
Land at stations.

The quantity of land required for a mile of railway depends upon the width as determined by the depth of cuttings and height of embankments. Assuming an average depth and height of 3 ft. and a slope of 1½ to 1 (which is that usual for alluvial soil), from 5 to 6 acres will be required per mile of single-line standard-gauge railway made in the manner usual in England. For each foot deducted from or added to the average depth and height, one yard in width or 1,760 yards per mile (about ⅜ acre) must—if the same angle of 1½ to 1 be maintained—be deducted from or added to the acreage given above. These quantities are exclusive of land for sidings and stations. It is always advisable for a railway company to secure surplus land at stations, because such land will be invaluable if additional buildings or sidings are afterwards required; while, owing to the enhanced value which land in the neighbourhood of stations acquires, it can be re-sold with advantage, if it be not permanently required for the railway.

It is usual in constructing a single-line railway to make certain provisions for converting it into a double line afterwards. Thus land enough for a double line is purchased, the single line being constructed on one side, as indicated above; bridges over the railway are constructed of a sufficient span; the masonry abutments of under-bridges built for the double line, the floor or road on such bridges being at first only made for the single line.



CUTTING



EMBANKMENT

Efficient narrow-gauge lines.

So much has the standard gauge been associated with railways, that it is difficult for those who have seen no others to realise the efficient services that can be rendered by narrow-gauge lines. Commencing from the very smallest, railways of from 10 in. to 24 in.

gauge are sufficient for continuous and heavy services in warehouses, factories, quarries, and mines, and such lines have the advantage not only of economising cost, but space also, as they can be constructed with sharp curves, and made to branch into places where, without them, it would be impossible to move heavy loads cheaply or even at all. The narrower of such lines should in strictness be called tram-roads, as it is only when a gauge of 18 in. is reached that the use of locomotives becomes profitable or expedient. The smallest gauges on which locomotives work continuously, and with regard to whose efficiency trustworthy experience has been gained, are the railway at the Crewe Locomotive Factory of the London and North-Western Railway; the railways in Woolwich Arsenal, and Chatham Dockyard; and the Festiniog Railway, in North Wales. At Woolwich, Chatham, and Crewe these small railways merely supplement the lines of standard gauge by which communication with the railways of the kingdom is maintained. The Festiniog Railway, in North Wales, which has been visited by numberless persons desirous of information, is interesting and useful as an example of what may be done under certain conditions; but discrimination is needed in drawing conclusions from its success. The exceptional shape, weight, and uniformity of the loads (slate) which are carried, the solidity of the permanent way, the nature of the cuttings, tunnels, and other works, and the exceptional feature that nine-tenths of the paying loads are taken down-hill, are all circumstances which must be weighed against the corresponding conditions in any new case which demands consideration.

Minimum gauge for locomotives.

Examples.

See also page 63.

Festiniog Railway

In many foreign countries there is not the same necessity as in England for heavily-made wide-gauge railways; or, whatever be the necessity, the want of money precludes their construction. For such cases, light narrow-gauge railways may be adopted with advantage. When the traffic consists only of passengers and of produce or merchandise in light pieces or packages, there is no necessity for the heavy rolling-stock, the heavy locomotives, and the consequent heavy permanent-way, nor for the strong under-bridges required by ordinary railways. It is the lightness of the locomotives, and not the mere reduction in gauge which allows economy in construction, and if it be attempted to obtain economy by light construction without reduction of gauge, there will often be the risk that heavy locomotives from neighbouring railways will some day come upon the line and injure the permanent way

Light railways.

Light locomotives.

and bridges. In countries where a low first cost is of importance, and where no great natural obstacles present themselves, the advantages of railway communication can be obtained very cheaply; and in regard to the public convenience, the difference between having no railway at all and having a light railway is immensely greater than the difference between having a light railway and a heavy one. It sometimes happens in a new or half-civilised country that no public spirit or belief in railways can be aroused till one is seen in actual operation; and these also are cases for light lines and cheap first cost. An example of this is afforded by the experimental line constructed in China in 1876.

Railways in new countries.

Advantages of narrow gauge.

Narrow-gauge railways allow of sharp curves by which the contour lines of hills may be followed; thus in most cases avoiding tunnels, large bridges, and heavy earthworks which, with the standard gauge, would be inevitable. In flat or gently undulating countries, light narrow-gauge single-line railways may be constructed very cheaply, as the approximate prices given on page 64 will indicate; and such railways can generally be made to earn a revenue at once. In the construction of new railways in the United States, the system is sometimes adopted of laying the line in the first instance roughly but rapidly; trusting that the trains when once running will provide a means for after ballasting; heavier rails and stronger permanent-way being substituted with accruing revenue as traffic increases. This method is not generally approved by English engineers; but before condemning such a system, the circumstances which led to it must be considered; and it is questionable if the long new lines across prairies and deserts would have been constructed at all if it had not been for the rapid progress which such hasty methods allowed. Even if this system be adopted, it is desirable to avoid any alteration of gauge, which should remain fixed from the first.

Rapid construction.

Ballasting.

Choice of gauge

If a railway is to be made of a gauge less than the standard, it is always desirable to choose some gauge already in use, so as to utilise existing patterns in rolling-stock, and to obtain the advantage of experience already acquired as to design and the proper proportion of parts in regard to the equipment of the railway. The narrow gauges tabulated on page 64 are those which for the above—among other—reasons are most likely to be adopted for the future. In the following list are enumerated various gauges already adopted in different countries. Those marked † are in course of alteration to the standard gauge. The list is not an exhaustive one.

List of gauges in different countries.

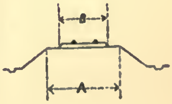
Gauge.		
ft.	in.	
†7	0¾	Brunel's gauge on the Great Western Railway in England and Wales.
†6	0	In the U. S. of America (Erie).
5	6	In Spain, Portugal, Canada,† India, Ceylon, Chili, Argent. Repub.
5	3	In Ireland, Brazil, Victoria, S. Australia, Tasmania (Launceston), N. Zealand (Lyttleton).
5	0	In Russia; U. S. of America (Southern States).
4	11½	In Sardinia.
4	9	In the U. S. of America (Pennsylvania).
4	**8½**	(*Standard Gauge*). In Great Britain, France, Belgium, Holland, Germany, Austria, Italy, Norway, Denmark, Sweden, Switzerland, Canada, U. S. of America, Central America, Peru, Cape of Good Hope, N. S. Wales, Egypt, Mauritius, Java.
4	2	South America (Carrizal Ry., Chili).
4	0	Sweden† (Uddevalla), India (Nalhati).
3	9	In Spain (Galdames and Sestao Ry., Bilbao).
3	7⅜	(1.10 *m.*) In Belgium (Antwerp-Ghent).
3	6	In Norway, Sweden, Spain, Canada, I. of Man, S. Australia, W. Australia, Queensland, N. Zealand, Cape of Good Hope, Natal, Tasmania, Peru, Chili, Japan, Java.
3	3⅜	(*Metre*). In France, Spain, Brazil, Indian State Rys., S. Indian Ry.
3	0	In England (Ravenglass Ry., Cumberland), Sweden (Palsboda), U. S. of America (Denver and Rio Grande).
2	6	Wales (Talyllyn Ry.), Sweden (Kroppa), Bolivia, China (Experimental Line).
2	4½	In Hungary (Rostoken-Marksdorf).
2	0	In Venezuela (Bolivar Mineral Ry.)
1	11½	In Wales (Festiniog Ry.)
1	10	In Guinness' Brewery, Dublin.
1	6	In the Locomotive Factory, Crewe. L. & N. W. Ry.; Woolwich Arsenal; Chatham Dockyard.

Little railways.

The following may be given as the approximate cost of light narrow-gauge railways (single line), including works and rolling-stock, but not land. A moderate but sufficient amount of ballast is assumed, and more can be added as the traffic demands heavier engines or quicker speed. On English main lines of standard gauge, with heavy trains running at high speeds, ballast 20 in. to 24 in. deep is provided.

Ballast on light railways.

For the gauges up to 2 ft. 6 in., an 8 ft. width of formation A is assumed, ballast B 4 ft. 6 in. wide and 6 in. to 9 in. deep; and embankments and cuttings averaging 18 in. For the gauges above 2 ft. 6 in.



a 10 ft. width of formation, ballast 6 ft. wide and 9 in. to 14 in. deep; and embankments and cuttings averaging 2 ft. are assumed.

Cost of light railways.

See in Part II. RAILWAY EQUIPMENT *and* ROLLING-STOCK.

Gauge.		Weight of Engines exclusive of Tender.		Weight per Yard of each Rail.	Cost per Mile.		
ft.	in.	Tons.	Maximum load per wheel. Tons.	lbs.	£		£
2	0	6	1	20	1,500	to	2,000
2	6	9	1½	25	2,500	"	3,000
3	0	12	2	30	3,000	"	3,500
3	3⅜	17	3	40	3,500	"	4,500
3	6	20	3½	50	4,000	"	5,000

Severance avoided.

See also page 3.

There is no fixed proportion between the quantity of land required for a narrow-gauge, and that for a standard-gauge railway. For instance, in the case of cuttings with wide sloping banks, it is obvious that the mere saving in width of formation would bear but a slight proportion to the quantity of surface land, which—whatever the gauge—would be required. But, even in a level country, narrow-gauge lines allow but a comparatively slight saving in land; the economy of such systems being rather in the easier traction which the lighter rolling-stock requires, and in the sharper curves, and therefore greater choice of route. A narrow-gauge line allows an indirect saving also, because by its sharper curves it may more conveniently be made to follow the boundary lines of property, and so avoid the "severance" which—because of the compensation allowed to the land-owners—has proved so expensive in the case of many standard-gauge railways in England.

The cost of construction having been arrived at, there remain, in order to complete the estimate of probable profits, the other points, stated on page 56, *i.e.*—

II. *The Expenses of Working and Maintenance.*
III. *The Revenue.*

These may be conveniently taken together, and the proportion which they bear to each other determines of course the amount of net profit which will be available for dividends.

For the working and maintenance, there are standards by which to measure approximately the probable cost, but these need qualifica-

Expenses of working and maintenance.

tion. In England, for instance, the cost on the principal main trunk lines is from 45 to 60 per cent. of the gross earnings, 55 per cent. being the average of the United Kingdom. But through a given country yielding a certain amount of traffic, a railway 100 miles long may pay well, while a railway only ten miles long in the same district, and with all conditions but length exactly similar, may not even pay working expenses. For on each mile of the shorter line there will be little if any more than the local traffic resulting from the necessities or products of a district ten miles long. But on each mile of the longer line, besides the business of the district immediately surrounding it, there is also the through traffic of the whole 100 miles; the number of stations between which traffic can be exchanged being greater, and the average distance hauled, longer. In other words, the receipts per train-mile will be much larger on the longer than on the shorter railway, while the expense per train-mile ought to be less, because the terminal and other station charges bear a smaller proportion to the total earned; and the expenses of equipment and working will also be less, inasmuch as a less percentage of spare and idle stock is required, the engines and men having their time more completely filled up.

Expenses great on short railways.

Convenient lengths for working.

There are certain convenient lengths of line which allow of economical working. From 45 to 60 miles are such lengths for goods traffic, because a locomotive can work for this distance and back again in one day, and so both engine and men are fully employed. Passenger engines can work from 70 to 100 miles and back again per day, according to speed and other conditions, but if made up of numerous short journeys, a total of from 100 to 120 miles could only be obtained.

Cost of working per train-mile.

It costs a certain definite sum to work a train for a mile; two shillings may be taken as a minimum, and some amount between two and three shillings will embrace the great proportion of all railway working for ordinary trains in England; these sums including all the charges of the railway except that of interest on capital. These limits are, however, exceeded in the cases of heavy express-trains and heavy goods-trains.

Train-mile unit unsatisfactory.

Although the "train-mile" is the unit generally adopted in England for statements of the cost of railway working, it is not a wholly satisfactory unit, because, as the power for working different kinds of trains on different gradients must obviously vary very much, no mere statement of cost per train-mile on different railways will allow

See also LOCOMOTIVES *in Part II.*

a proper comparison, unless the various circumstances are also taken into account. Moreover, the nominal distance run by a locomotive is often increased by the shunting at stations, and the terminal service required, so that on a line with frequent stations, a nominal 50 miles may equal a run of 70 miles on another railway.

Revenue.

Unless the earnings per train-mile exceed the cost of working, the line manifestly cannot be remunerative, however cheaply it may have been made. Assuming that the line can be maintained and worked for 50 per cent. of the gross earnings, the revenue which will be required to pay a dividend on a certain capital expenditure becomes a simple matter of calculation. Thus for a railway which is to cost £5,000 per mile, a revenue of £9 12s. per mile per week will be necessary to pay 5 per cent. dividend: for a railway costing £6,000 per mile, a revenue of £11 10s. per mile per week, and so on. Obvious as this may appear, it is unfortunately true that many railways have been constructed without sufficient investigation beforehand into the proportion which the revenue will bear to the cost of construction and working; and, however desirable it may be to have a standard-gauge line, with strongly-constructed works and high-class accommodation, the cost must be brought to accord with the revenue, unless there be special reasons to justify a contrary course. Thus the capitalists may be sanguine enough to expect a considerable growth of revenue when the advantages afforded by the railway are developed, and for this reason may be willing to commence with a dividend lower than 5 per cent.; or the railway may benefit other property in which the promoters are interested, and which may compensate for a small dividend on the capital in the railway. In the latter case, ordinary investors, who may have been allured by the example set them by capitalists thus prompted by ulterior motives, will find themselves disappointed. It is in cases where advantages expected to accrue are indirect or prospective, that guarantees become necessary or State railways expedient.

Per mile per week.

Prospective revenue.

See INDIA, *page 32.*

Short lines unremunerative.

A short branch line, on which the working and management charges may be unavoidably high, is hardly ever remunerative *per se*, although as part of a large railway system it may pay, because of the traffic it takes to and receives from the main line. The future prosperity of a new railway will be found to depend very much upon whether it is to form part of a main trunk line, or whether as a spur or branch it will never become more than a local line. In some such cases a break of gauge may be justified,

Break of gauge justified.

for, as capitalists—presumably—will not provide money for a standard gauge where a sufficient return is impossible, a light narrow-gauge "feeder" line may be constructed, rather than leave the district without railway accommodation; the cost of transfer (about 6d. per ton) at the junction of the different gauges being provided for in the rates charged for carriage. Light railways of this description may be likened to omnibus and cart traffic bringing passengers and goods to a railway station, the transport on the light railway being cheaper and more efficient. For instance, such a branch railway can be made from a trunk line to a coast-town, where the traffic is too small to pay for a standard-gauge line, and where, from the position of the town on the coast, the branch can never be extended, or be anything more than a spur. There are railways whose earnings do not pay the working expenses; and reference has already been made to such lines to show that even a guaranteed interest on capital may prove fallacious, where a portion of such interest has to be applied to pay current expenses.

Feeder-lines.

See page 32.

The nature and amount of the traffic to be carried; the gradients to be overcome; the cost of coal and wages; and a variety of other circumstances, technical and economical, determine the cost of working. The best resolution of the several problems can only be arrived at by considering them together at the outset; but if, as too frequently happens, a railway be made in a certain way simply because other railways have been so made, it may prove unsuitable and therefore unremunerative. It is beside the present purpose, and it would be impossible here, to discuss all these circumstances. It is only here intended to emphasise the axiom that no fixed rule can be laid down for railway enterprise; that it is dangerous to calculate by precedent unless all the circumstances are similar; and that only when possessed of the fullest local information can those who are experienced in such matters advise as to the best methods of attaining success.

Cost of working, how determined.

Fixed rules fallacious.

If a railway scheme is brought forward in the nature of a concession, the remarks in the preceding chapters on foreign enterprises generally, will more or less apply; what follows here is of special application to railways. If a contractor be asked to tender for the construction of a foreign railway, he will of course examine the country, either personally or by his agents; and able contractors will be the more willing to incur the trouble and expense of such a survey if the preliminary information supplied to them be full and explicit.

Concessions.

See Chapters II. and III.

Capital provided by contractors.
See also pages 39 to 43.

Information necessary.
See pages 18 to 24.

If the contractors are to be paid directly in money for their work, they will only have to satisfy themselves that the terms are remunerative, and that those who have to make the stipulated payments may be relied on; and then to direct their attention to the examination of plans and to the local investigation that are necessary to a correct estimate of the cost. But it is sometimes the case that concessionnaires or contractors are required to provide some or all of the capital; or it may be that the payments are to be partly dependent on or secured by the revenue. The contractors will in such cases require special information as to the financial merits of the scheme; the data upon which the estimates of future expenses and revenue have been based; and generally as to the points which have been already suggested under the head of concessions. These and various other points may now be summed up and enumerated in the following list; and according to the nature of the case, and the conditions under which the works are to be undertaken, some or all will be found to apply. It will be seen that some of the information required is purely local, and such as can be afforded by any intelligent person who knows the country, while other queries involve technical knowledge and a survey of the route. Sometimes the capitalists and contractors whose aid is sought to construct a railway, prefer to choose the exact route themselves, and to employ their own engineer to make the plans. But even then they will the more readily undertake the expense of a survey if the promoters can furnish them with such local information as may guide them in forming a preliminary and approximate estimate of expenditure and profit.

Particulars classified.

The following list has been made to include the more precise information which must be obtained by those concerned before an actual contract can be made; and it would not be all expected at the outset of an undertaking:—

Map.

1. A general map of the country showing existing railways, roads, canals, rivers, and the route proposed for the new line.

Utility.

2. The supposed utility of the new railway, and the reasons generally which have suggested its construction.

Powers.

3. The legal powers under which the line is to be built, and the nature of the permission or concession granted.

Plan of railway.
Limits of deviation
See also page 3.

4. A plan of the line itself, showing, on a larger scale than the general map, the rivers and roads to be crossed, the towns and villages to be passed, and the limits of deviation which the concession allows.

Population.

5. The population of the various places on and adjacent to the railway, and the kind of trade or occupation in which the inhabitants are engaged. The positions of factories and mills near to the line of railway should be indicated on the map.

Traffic and revenue.

6. The nature and amount of traffic anticipated, and the calculations of revenue based thereon. Some assistance in verifying such calculations will be afforded by a description of the means of transport already existing, and the rates paid for freight and passengers. The importance—even to the contractor—of estimating correctly the revenue expected from public works is not always sufficiently appreciated. For instance, where a contractor is to be paid partly in money and partly in obligations, he may deem himself safe, if for the latter portion of his payment he has a first charge on the revenue, which is to be created by an expenditure five or ten times the amount of his claim. But it may happen that the undertaking will only pay its bare working expenses; and evidently no degree of preference will be of value when the net revenue is *nil.*

Width of gauge and strength of works.

7. Information as to the traffic will of course to a large extent determine the width of gauge, the choice of a single or double line, the strength and kind of works, and similar important questions. If a single or double line has been decided on, it should be so stated, and also the width of gauge. If, however, the width of gauge is left an open question, any local reasons for or against a narrow or standard gauge should be stated. The gauge of neighbouring railways, or those to which the new line may some day be joined, will, in conjunction with the information described in the preceding and following clauses, have considerable weight in determining the question.

See page 57.

Sections and gradients.

8. A section of the line on a large scale showing the proposed gradients, the cuttings, embankments, tunnels, and bridges required. If any large or expensive works of this sort are needed, the plan should indicate any alternative routes that are possible, so that the comparative advantages of various gradients involving greater or less distances, and cheap or expensive works, may be duly weighed. The preliminary survey and rough sections considered sufficient in the early stages of a proposed new railway scheme in England have been already described.

See page 3.

Geological information.

9. Information as to the nature of the soil; the strata in tunnels and cuttings; and an account of the investigations or the geological evidence on which the facts adduced are based. In the case of

tunnels, the sections should be made to show clearly whether intermediate shafts can be sunk, or whether excavation can proceed only from the two extremities. This is important both as regards the time to be occupied in the works, and their cost. The strata above the tunnel should be described, and evidence supplied as to the probable presence of water.

See BRIDGES.

10. In the case of large or important bridges, special information should be afforded for estimating approximately the cost.

Building materials.

Timber.

11. An account of the timber, stone, clay, lime, ballast, and other materials that are to be obtained in the neighbourhood of the railway, and at what cost. The suitability of the timber for bridges, piles, staging, and sleepers is an important point to be noticed, and if railways already exist in the country, the system of permanent-way which has been found best should be described. A description of the horses or other beasts of burden which are obtainable, and their cost, together with that of forage. The kinds of coal or other fuel, and the water, that will be available for locomotives; the places where they are to be found, in what quantity, and at what cost.

Horses and forage

Coal and water.

Transport and Taxes.

See also EXPORT *in Part II.*

12. The facilities for landing and transporting materials that may have to be sent from England; the dues, import duties, or taxes that may have to be paid.

Climate.

13. The nature of the climate, and its effect upon health; the restrictions which it imposes upon the hours of labour; the destructive effects (if any) it may have upon timber and other materials. Heavy, frequent, or incessant rains; liability to earthquakes, floods, hurricanes, frosts, and snowstorms, also come under this head. Continual or frequent moisture, which would, by making the rails slippery, reduce the adhesion and tractive force of locomotives, is an important incident, especially where there are steep gradients.

See LOCOMOTIVES *in Part II.*

Workmen.

Cheap labour fallacious.

14. The kind of workmen that are to be obtained in the country, or in adjacent countries. In localities where the wages are low, it is sometimes assumed that works can be very cheaply executed, but as a general rule it will be found that whatever the nominal wages for unskilled labour may be, the real cost, as measured by the work executed, is about the same everywhere. In case, however, skilled labour has to be brought from England or other considerable distance, the expense is, of course, greater than where such workmen are to be found on the spot. If workmen have to be taken to the district, it is necessary to know if food and lodging can be readily obtained for them, because if houses and provisions have to be

provided by the contractor (as sometimes happens), his expenses are much increased.

Acquisition of land. *See also pages 16 and 25.*

15. The conditions upon which the land has been or is to be acquired, and whether the railway project is popular or otherwise among the landowners. If the land has to be paid for by the contractors, very trustworthy and exact information must be supplied as to the prices: the certainty of obtaining immediate possession: and as to whether, and how far, shares or obligations of the railway will be accepted in payment.

Quality of works and equipment.

16. The conditions, if any, that have been made by the authorities who grant the concession as to the kind of works, width of gauge, gradients, engines, weight of rails, length of sidings, number and kind of station-buildings and amount of rolling-stock. It is on these points that differences of opinion often arise. If these matters are not adjusted beforehand by persons of experience, difficulties and disputes are almost sure to occur before the final settlement. It not unfrequently happens that those in a country or district who, perhaps, may have to bear a share of the cost, offer impossible conditions. They require everything of the best, a wide gauge, easy gradients, heavy rails, strongly-constructed works, and perfect equipment, and, at the same time, assume as sufficient a price entirely inadequate. In some such cases, the cost of a neighbouring line is quoted as a precedent, though the conditions may be very different. In other such cases, the preliminary estimate of cost is based upon the report of some official or friendly engineer, who, having themselves no risk, look at everything from the brightest possible point of view. A contractor, on the other hand, has to provide against contingencies which he knows from experience are almost sure to occur.

Preliminary estimates.

Contingencies.

Interchange of traffic.

Running powers.

17. The terms on which interchange of traffic will, or may be, carried on with adjoining railways should be stated; for if the proposed railway is intended to join existing lines, great care is necessary in arranging beforehand equitable terms for rates, running powers, and station accommodation. If left unsettled till the new line be made, a previously existing railway company, having the command of important accommodation, may make terms onerous enough to absorb the profits of the new railway.

Terms of payment *See pages 11, 22, 40.*

18. Reference has been made to some different modes of payment. Where the payments for work accomplished are to be made regularly in money, and the credit of those who promise to pay is

unquestionable, there will be no lack of contractors to undertake the contract, if it is large enough to be worth the trouble. The periods and amounts of the payments are important points for the consideration of contractors. It is usual to retain a certain percentage of the agreed payments until the whole of the works are completed and upheld for some months afterwards; but where the total amount of the contract is large, and the works will occupy a long time, it is not unusual to limit the retention to a certain sum, beyond which the payments are to be made in full. Thus, for example, in a contract for £400,000, with a retention of 10 per cent., it is not unreasonable that when half the works are completed, the retention of the £20,000 then accumulated shall be considered a sufficient retention to hold till the last for the fulfilment of the contract, and that the remainder shall be paid as earned without deduction. Where more money is retained than is necessary for this purpose of security, it is really at the expense of the buyer, as the contractor will naturally recoup himself by higher charges for his loss of interest, which will probably be greater than that which will be gained by the buyer who holds back the money. Besides, when a larger sum than is necessary is retained, it may with some justice be inferred that inability, and not mere disinclination to pay, is the reason; and the contract then comes within the category of those with deferred payments, and its cost is estimated accordingly.

Retention.

See also page 36.

Amount of retention limited.

See page 49.

The more detailed information which is required for deciding upon the description, and for estimating the cost, of permanent-way and the other equipment of a railway, will be found in later chapters.

See in Part II.

[*See also* PARLIAMENTARY PROCEDURE: CONCESSIONS: BRIDGES: TRAMWAYS: *and in* PART II., RAILWAY EQUIPMENT: LOCOMOTIVES: ROLLING-STOCK.]

CHAPTER V.

TELEGRAPHS. LAND-LINES. UNDERGROUND WIRES. PNEUMATIC TUBES. SUBMARINE CABLES.

TELEGRAPHY, or the use of signals for transmitting intelligence from place to place, has existed from ancient times in all countries, more or less, according to their civilisation. The modes of signalling were improved in various ways, in different European countries, during the eighteenth century, and were brought to a high degree of perfection in England during the long French war which ended at Waterloo. By means of semaphore and shutter telegraphs the Government in London held communication with the principal outports; and, as simple messages could be sent from London to Portsmouth in five minutes, such facilities were, during times of war and threatened invasion, of great value. Such a method of communication was, however, limited to daylight, and was liable to be stopped by fog. Semaphore telegraphs are still used for military purposes, and are useful for signalling across harbours or rivers, or to and from ships at sea. The codes of signals have been improved and simplified, and can be and are arranged so that the same system can be adapted to night-signalling by lanterns or flashes of light. Indeed, the electric-telegraph code of Morse is only an application of the same principle; as also are the various military and naval codes by flags, lanterns, and light-flashes.

Semaphore telegraphs.

Morse's code.

After the establishment of railways in 1830, the application of electricity to telegraphy—which followed in 1837—formed an important adjunct to the earlier enterprise, though the facilities afforded by the electric telegraph to the safety, management, and extension

Electric-telegraphs.

of railways have not always been sufficiently appreciated. For some time after 1837 the new telegraphs were confined almost entirely to the lines of railway, and the two undertakings became intimately associated in the public mind. The demand for telegraphs in all parts of the world, and their rapid extension, having necessarily directed the attention of many minds to the subject, continuous and valuable improvements have taken place, the great variety of conditions under which telegraph lines are constructed having taxed to the utmost the ingenuity of those concerned. It would appear as if every possible combination of circumstance and difficulty must have been encountered; but new cases are ever arising which demand new treatment. The improvements that have taken place are mainly in matters of detail; but telegraphs are essentially composed of details, and every fresh experience, however small, has had its value for the future.

Telegraphs associated with railways.

Improvements.

The construction of telegraphs in a new country is an enterprise of a speculative kind, because it offers to the community a convenience rather than a necessity: but in many cases the supply creates the demand. Where one merchant obtains early intelligence, competition obliges all to follow the example: and public opinion leaves the newspaper-press no alternative but to obtain the most recent news. The proprietors of a land-line can afford to wait for increased traffic, because, if properly constructed, the cost of its maintenance is small. Of course, much depends on the proportion which the capital bears to the possible returns. If the mercantile community be small or poor, or the line long or otherwise expensive, a fair return can hardly be expected; for, with small traffic, the rates, to be remunerative, must be high, and the line will be seldom used except in cases of emergency. In cases where the return to be expected is thus doubtful, capitalists will require something more than mere permission to induce them to embark in the enterprise; and assistance or encouragement must be afforded them, in the shape of monopoly, guarantee, subsidy, or otherwise. But whatever be the nature of the assistance thus rendered by the Government of a country, it is, in almost all cases, important for a telegraph company to obtain rights of way for the erection of the poles, and to secure protection of the line by Government decrees.

Telegraph undertakings speculative.

Increase of traffic may be expected.

Concessions.

See Chapters II. and III.

See pages 26 to 32.

Rights of way.

Where capitalists combine to construct land-telegraphs, it is generally through the medium of a joint-stock company, and on the basis of estimates furnished by engineers and contractors who have surveyed the line. The kind of information necessary to such estimates is described further on. Although a considerable proportion of the telegraphs of the world are still in the hands of private companies, there appears to be a tendency towards the purchase of existing lines, and to the projection of new lines, by Governments who are in a position to work them economically by existing post-office or other departmental organisation. It is obvious that a Government may legitimately construct for the general benefit of the community, new lines which might not prove sufficiently remunerative to private capitalists as a separate undertaking. As regards new land-lines, telegraph contractors, and those capitalists who assist them, look rather to the contractors' profit, than to the permanent investment in them for the sake of a return revenue. Under such circumstances, a Government will generally grant to the contractors facilities or immunities of the kind already mentioned for railways; and will themselves take precautions for the protection of the line when finished. As, for the maintenance and working of telegraphs a special technical knowledge is required, and this, though readily acquired under tuition, is not easily procurable in countries where few or no previous telegraphs exist, it is often stipulated that the contractors shall not only maintain the line in good condition for a certain period, but shall for a short time actually work the line and instruct the officials in their new duties.

See pages 83—85.

Government telegraphs.

Facilities and immunities. *See page 25.*

Instruction to operators.

In the construction of telegraphs the functions of the electrician are to a large extent absorbed in those of the engineer; and those who devote themselves to such undertakings are classed as Telegraph Engineers. Some of the principal land-lines of the world have been laid in the face of almost insuperable obstacles, and pre-eminent among such lines are the Indo-European; the Great Northern of Russia; the line north to south across Australia; and the Trans-andine line from Buenos Ayres to Valparaiso, through the Pampas, and across the snow region of the Andes.

Telegraph engineers.

Examples of difficult routes.

The construction of the land lines between England and India may be specially cited as conspicuous feats of modern enterprise. The difficulties were so numerous and varied as to demand, besides the skill of the electrician and the resources of the engineer, the perseverance of the explorer and the astuteness of the politician. The physical difficulties were great: deserts had to be crossed, wide rivers spanned, and mountain ranges surmounted. Intense heat in one part of the route rendered work almost unbearable: extreme

Indo-European telegraphs.

Special skill required.

Difficulties of climate.

Local opposition.

cold in other districts buried poles and wires for miles in snow: heavy rains rendered insulation almost impossible; while the poles were destroyed by beasts and vermin. The local opposition was of the most aggravating kind; for not only were there avowed enemies who had to be conquered, but mischievous natives who obstructed the work in various ways. When at last, after recourse to punishment, cajolery, and bribes, the line was completed and its maintenance ensured, political or national jealousy of the European servants, and the consequent employment of inert and incapable natives, rendered a regular service impossible.

Messages delayed.

Difficulties overcome.

Thus hindered, messages from England to India, for some time after the completion of the telegraph, took from four to ten days in passing. So successful, however, were the combined efforts of those concerned, and so completely were all difficulties conquered, that the time occupied in the transmission of through messages from London, *viâ* Germany, Russia, Persia, thence by cable through the Indian Ocean to Kurrachee, and by long land-lines to Calcutta, has been brought down (1877) to an average of ninety minutes. To the officers of the Royal Engineers who had the management of the telegraphs, and who, with their civil assistants, surveyed, constructed, and maintained the line, these results are due; and the history of their enterprise is one of the most interesting among the many records which are available for future guidance.

Materials for telegraphs.

Wooden poles.

The principal materials employed for land-lines are the poles, the insulators, and the wire. In England, wood poles are generally used—larch, Memel fir, and Norway red fir being the sorts best for the purpose. But wooden poles decay, their term of endurance depending upon their quality, on the skill with which they have been selected and prepared, and on the climate and soil to which they are exposed.

Cost of wooden poles.

In England, native larch is occasionally obtainable; but the great bulk of the poles for telegraphs are imported from the Baltic timber countries. The poles selected for this purpose range from 25 ft. to 40 ft. in length; although, for single-wire lines, poles even shorter than 25 ft., and for special purposes long poles of from 50 to 60 ft., are sometimes employed. The cost of wood poles, as delivered from the ship in England, is stated at per lineal foot, the prices ranging from about 3d. per foot for poles 25 ft. long and 5 in. diameter at the top, to about 7d. per foot for poles 40 ft. long and

6 in. diameter at the top. These prices are equivalent to about 1s. 6d. per cubic foot, or 75s. per load of 50 ft.; and, at this rate, the poles vary in price from 6s. to 22s. each. One "load" weighs about 1 ton, and measures about 1¼ tons for freight. After the poles arrive in England, and—if for exportation—before they are re-shipped, they are generally creosoted, burnetised, boucherised, or in some analogous way prepared to resist moisture and decay, this treatment adding from 4d. to 6d. per cubic foot to their cost. Sometimes—especially for native poles in foreign countries where the above chemical processes cannot be applied—the ends which are to be inserted in the ground are merely charred. For countries where native-grown poles are not obtainable, or where because of climate or destructive insects wood is useless, iron poles sent from England are generally used: iron poles are also preferable, because of their strength to resist hurricanes, and because of the facility they afford for transport in pieces. Iron poles are made in a variety of ways, of cast or wrought iron, or of the two combined, the choice of design depending on the length of span, the number of wires, the strength of the wind, and the exigencies of transport. Climate, also, and contiguity of the sea, affect cast and wrought iron differently. Great ingenuity is shown in the construction of the poles for convenience of carriage, and for facility of erection. Iron poles vary in weight from 100 to 350 lbs. each, but the larger proportion are of some weight between 180 and 250 lbs., and it is doubtful economy to employ for a permanent line an iron pole weighing less than 200 lbs. Iron poles within the above limits of weight are about 20 ft. long, and cost from 25s. to 40s. each. But in countries subject to violent winds or hurricanes, or where wild animals abound, or where long river spans have to be supported, it is necessary to provide very strong poles, and the iron masts erected in such cases are heavy and expensive.

Poles chemically preserved.

Charred ends.

Iron poles.

Division of poles for carriage.

Weight and cost of iron poles.

Poles are usually placed at intervals of from 60 to 90 yards, twenty to twenty-eight poles being used to the mile, according to circumstances. But when occasion requires, as in the crossing of rivers or ravines, much longer spans are adopted. The Thames is crossed at various points by wires 800 ft. between supports, while over the wider rivers of the Continent, and over many American rivers, single spans of from 1,000 to 2,000 ft. are frequently carried. In these cases the conductors are either formed of twisted strands or of homogeneous steel wire, so as to obtain the sufficient strength to resist the strain. In some cases the conductor-wire is kept free from all strain by

Number of poles per mile.

Long spans.

Mode of suspension.

Aerial cables.

attaching it to two wires used for the purposes of suspension only. This course is generally adopted where more than one conductor has to be carried, to avoid the possible contact of many separate wires, or in cities where frequent supports for a large number of wires are not easily obtained; and in these cases, light aerial cables are hung from the upper wire by hooks or links, placed 20 ft. to 50 ft. apart. The conductors in such cables are of copper wires twisted into strands and coated with gutta-percha; and the required number of these conductors are formed into one cable and covered with tarred hemp. The aerial cables, containing five wires, are about ⅜ in. diameter, and cables of a diameter greater than ¾ in. are seldom used.

Insulators.

Cost of insulators.

There is an almost endless variety of insulators, which are made either of earthenware, porcelain, glass, or ebonite, and sometimes with cast-iron or malleable cast-iron protecting hoods. The choice depends on various practical considerations besides those special to the electrician. Such considerations are the mode of fixing the insulators to the pole and of attaching the wire, the resistance to moisture or decay, facility of transport, and resistance to fracture. The leakage of electricity through the insulators from the line-wire to the earth, which always takes place to a certain extent, becomes in its aggregate sometimes a serious difficulty in the case of a long line and a damp climate; and to prevent this leakage as far as possible, it is necessary to employ the best kinds of insulators and to keep them in perfect condition. On short lines good insulation is of less importance, and therefore less perfect insulators may be used. Ordinary earthenware insulators cost about 1s. each; but the better sort of porcelain insulators, with iron hoods, cost from 1s. 9d. to 2s. 6d. each, and weigh from 2 to 3 lbs. At intervals—every sixth, eighth, or tenth pole, according to circumstances—straining-insulators are placed, and these weigh and cost about double the simple kind.

Wire.

Diameter of wire.

The wire used for land-lines is generally of iron, and is usually galvanised (coated with zinc), but it may be used black (oiled only) in dry countries; in any case, the wire should be most carefully selected and be of the best quality. Copper wire is expensive, and is too ductile for suspended land-lines, but for underground or submarine cables it is always used. The diameter or thickness of wire is stated not only by fractions of inches, or *millimetres*, but by the Birmingham Wire Gauge, and iron wire for permanent lines should not be less in diameter than No. 8 B. W. G. (=0·157 in., or 4·17 *mm.*), stouter wire up to No. 4 B. W. G. (=0.236 in. or 6 *mm.*)

being used in the construction of exceptionally strong lines, smaller diameters than No. 8 being only employed for temporary lines: 500 yards of No. 8 wire, galvanised, weigh 100 lbs., and cost in England about £1. The thicker wire, however, is not only stronger and more durable, but is more efficient as a conductor; and so much is this the case, that where the insulation is defective a wire of large diameter—say No. 6 or No. 4—will greatly neutralise the evils of leakage. The cost and inconveniences of transport are in some cases so great, that the ingenuity of engineers has been taxed to combine sufficient strength and conducting power with moderate weight. One method is that of using a light steel wire, round which is twisted a strip or riband of copper, and the wire and copper thus united are soldered together and tinned. The conducting power of the copper and the strength of the steel are thus happily combined; and this compound wire, as it is called, is only one-half the diameter and one-third of the weight of simple wire of equal conductivity and strength. It is, however, much more costly. By its lightness the strains on the insulators and the poles are reduced, and a reduction in the weight of these materials, as well as in that of the wire itself, allows a saving in transport which in cases where carriage is expensive, repays the extra cost of the compound wire.

Light wire for transport.

Compound wire.

Great care and judgment are necessary in choosing a route across a new country. Where roads or railways already exist, it is generally advisable to construct the telegraph along or parallel with the same line, thus facilitating the transport of material and access for inspection and repairs. But it often happens that there are no roads in the required direction, and—the telegraph having to be constructed across country—mountain-ranges, rivers, and other difficulties have to be conquered.

Choice of route.

For crossing rivers, the alternative advantages of an overhead and of a submerged wire have to be considered. Where the banks are high, and where poles can be erected so that the catenary wire will clear the masts of passing vessels, such a plan may be preferred. The curve or dip of the wire may be assumed as about one-fiftieth of the span. In some cases where the passage of masted vessels is rare, the wire has even been lowered into the water at such times so that the vessel may pass over it. There are many rivers which, though wide, have only a narrow navigable channel, and in such cases masts may be inserted in the bed of the river except at the navigable part.

Crossing of rivers.

Overhead wires.

Screw-pile masts.

Submerged cables for rivers.

See CABLES, *page* 89.

So also masts may be erected on the lowlands adjoining a river liable to floods. As, however, struts or stay wires would, if attached to the masts, be exposed to floating *débris*, the masts must be inserted firmly enough—for instance, as screwed piles—to be independent of side supports. With all precautions, however, great inconvenience and loss have been suffered—particularly in America—from the destruction by hurricanes and floods of the overhead lines crossing wide rivers on masts standing in the stream; and in many such cases submerged cables have been substituted with advantage: the chief risk in regard to such cables being that from ships' anchors and moorings.

Forest clearings.

Injury to poles and insulators.

Penalties.

Subsidies for protecting the telegraph.

Superstition.

In passing through forests a clearing must be made, or the line in some way be kept clear of falling branches, and this danger is one reason against attaching the wire to growing trees. So also in forests or jungles; creepers which might reach the wire and destroy the insulation, or grass which might ignite and burn the poles, are contingencies to be provided against. Telegraph poles and wires are exposed to attack not only from wild birds and beasts, but from mankind also. Even in England, boys throw stones at the insulators, while in Persia the natives shoot at them. In cases like these the insulators should be protected by annealed (malleable cast-iron) hoods. Whether from animosity or ignorance, savages or hostile tribes will often damage the line sufficiently to interrupt communication. Sometimes theft is the cause of damage, and the wire and other material are coveted as articles of utility, for though galvanised wire cannot well be smithed, it possesses a value for various purposes. Because of these risks, insulators and other parts are in some cases deliberately contrived to be as valueless as possible for any but their proper purpose. Threats and punishment, as well as conciliation, have to be tried to protect the wire, and the engineers who constructed the long lines previously referred to had much curious experience in this respect. In some cases a salutary fear has been inspired by punishing the persons detected in damaging the line, and in others it has been found expedient to permanently protect the line, by granting a small but regular subsidy to the local authorities through whose districts the line passes. Superstition—as in China, where the natives say that their aerial gods are offended by the new-fangled structures—jealousy, or pure mischief, will tempt the inhabitants of a country to injure telegraph lines; but when the novelty has worn off, it has generally been found that the line is unmolested.

The cost of telegraphs.

Estimates.

See page 77.

Cheap lines.

Local contractors.

Average cost of land-lines.

Additional wires.

The cost of land-telegraphs depends on many considerations, the nature of which will be gathered from the preceding pages. One of the chief, and at the same time most uncertain, items of expense, consists of the poles, the choice of which is, as has been seen, determined mainly by climate and the facilities for transport. Therefore, in estimating the cost of land-lines, it will be convenient to consider separately this item. If wooden poles can be procured in the country, their cost can be best ascertained there; but it is not often that the necessary appliances for creosoting the poles are found in foreign countries. The cost of iron poles in England has been already stated; and if they are required, it remains to be estimated how much it will cost to carry them from England and lay them along the route, ready for erection. Assuming then that the poles are supplied, and have been deposited along the route free of cost to the contractor, and assuming also that the cost of transporting wire and other material from England and depositing along the route does not exceed £5 per ton, and that there are no import duties to be paid, then the cost of laying a single-wire line, including simple apparatus and instruments at stations (say one station every ten miles), will be from £25 per mile and upwards. It is only very favourable cases, however, that admit of the above minimum, and such cases are generally those where there is a capable local contractor ready to do the work for a moderate profit. By this means costly superintendence brought from a distance is avoided, and also the intermediary profits of numerous agents, promoters, and contractors. A cost of from £40 to £50 per mile is more usual; and inclusive of poles, but exclusive of buildings, the cost in foreign countries will be generally found somewhere between £50 and £80 per mile. In cases, however, where the difficulties of transport are very great, the cost reaches, and sometimes even exceeds, £100 per mile. If poles strong enough for numerous wires have been erected in the first instance, then the cost of fixing each new wire will be from £3 to £4 per mile, in addition to the cost of the wire and insulators, and of laying these along the line ready for use.

Efficient and permanent lines expensive.

Where telegraphs are constructed on a large scale, and where the material employed is chosen for efficiency and permanency, the expenditure is necessarily considerable; and when there have to be added heavy expenses for transport of material, for skilled superintendence brought from a distant country, and finally for establishment and staff charges, then the total acquires a magnitude apparently out of proportion to that incurred under less onerous conditions. For any but temporary lines, it is always true economy to have the best materials. The cost of transport and the other charges incurred after the material is purchased, bear so high a proportion to the total expense as to reduce greatly even the apparent saving in first cost which the use of inferior materials might allow; while such inferior materials involve the necessity for repairs and renewals, commencing almost from the time the line is opened for service.

Best materials should be used.

Temporary lines.

Land-telegraph lines for temporary use only can, under ordinary circumstances, be constructed very cheaply, and, if the exigencies of military service demand it, very quickly also. Much of the expense of ordinary telegraphs arises from the permanent nature of the work. Poles must be strong enough to carry the weight and withstand the strains of heavy wires, and, in many cases, of future additional wires: the poles, if of wood, must be chemically prepared to resist decay, and, whether of iron or wood, must be very firmly fixed in the ground. For temporary telegraph-lines, growing trees, light poles, or bamboos, will be sufficient. For permanent lines strong iron wire, which will stand constant or repeated heavy strains without elongation or fracture, is necessary; such wire is heavy for transport, and causes great strains on the poles and insulators. For temporary lines, and especially where there is only one wire, more deflection may be permitted, and therefore copper wire, which is a better conductor than iron, may be used, and only of small diameter, say 16 B.W.G., with only twenty poles to the mile. For permanent lines the choice of insulators is most important; they must be non-conductors, strong against fracture or decay, capable of resisting heavy strains and serviceable for insulation in wet weather. For temporary lines, insulators of a very rude kind may be sufficient, and in some cases may be avoided altogether. In certain conditions of season or climate (dryness is the principal condition), sufficient insulation has been maintained for 100 miles in a wire attached directly to bamboos or wooden poles. For field purposes, wire, insulated in gutta-percha, and fixed on small light canes, is frequently used, thus rendering poles unnecessary. A single copper wire covered with gutta-percha costs from £8 to £12 per mile, but for exposure to the weather a conductor formed of twisted strands and more effectually enveloped is preferable, and such covered conductors cost about £20 per mile. Another kind of light covered wire for military purposes, is com-

Light wires.

Cheap insulators.

Field-telegraphs.

Military lines.

posed of one conductor of twisted copper strands insulated with two or more coats of india-rubber, and finally with cotton tape or felt tape. Such conductors can be rapidly laid on the ground for a few miles, from a general's head-quarters to advanced posts; the conductor is light, supple, and elastic enough to suffer the passage of carts or artillery over it without destroying the continuity, and can be wound up on a reel and used again. Such conductors have an outside diameter of from $\frac{1}{4}$ in. to $\frac{5}{16}$ in., and cost from £25 to £40 per mile, according to size and weight.

Short lines.

See page 47

Telegraph-contractors in England will not undertake to erect very short lines in distant countries, except at a disproportionately high cost, as there is otherwise nothing to repay them for risks and general expenses which must, even in short lines, be incurred. Cases of this sort come within the category of undertakings which are too small; and such lines should be erected by local contractors, or under the superintendence of local engineers.

Projection of new lines.

Information necessary.

The following information, which can only be obtained by a proper survey, is necessary for enabling an engineer to choose the best route for a land-telegraph line, and to advise as to the kinds of material which are most suitable. The route having been chosen, and the materials and other conditions specified by the engineer, the same information enables a contractor to measure the cost of the work, and allows the prospects of success—financial and otherwise—to be estimated by the promoters. In the case of important lines, a contractor, before absolutely concluding a contract, will require—either personally or by his agents—to verify the information and to inspect the route:—

Map showing route.

Junction with existing lines.

1. A map of the country, showing the general direction of the line of telegraph and the alternative routes which appear suitable. The towns, villages, roads, railways, rivers, and canals should be indicated on the map, and the places at which it is proposed to have a telegraph station. Existing lines of telegraph in the district should be shown, or any with which the proposed new line can communicate, or which may in any way be in competition with it.

Nature of the soil.

Vegetation.

2. The miles along the route having been numbered on the map, a written description should be furnished of each mile, embodying the following particulars: the nature of the soil; the facilities, or otherwise, which it affords for the insertion of poles, and whether the holes can be dug or will have to be blasted; the trees, jungle, grass,

or other vegetation, and its character at different seasons of the year.

Forest clearings.

Mountains.

Crossing of rivers.

See CABLES, *page 89.*

3. If forests have to be traversed, the roads or tracks which exist should be indicated, their suitability for a telegraph-route described, and the amount of clearing which would be necessary to keep the wire insulated. If mountains or ravines have to be passed, sufficient description, aided by sketches, should be afforded, to show any difficulties which may have to be surmounted. In the case of rivers, a section should be given, showing their width, the steepness of the banks, the nature of the river-bed, the depth of water at various seasons and periods of flood, and the direction and strength of the current at these periods. It can then be decided whether the river can be spanned by a suspended wire, whether such a wire would be clear of passing vessels, or whether a submerged wire or cable would be more suitable. In regard to the latter point, the class of vessels, if any, which pass should be described, and the probabilities of risks from anchors.

Trees or timber for poles.

4. Particulars should be furnished of the trees, canes, or timber suitable for telegraph-poles which exist in the country, together with the locality where they are to be found, the quantity obtainable, the facilities for transport, and the prices.

Climate.

Moisture.

Destructive agencies.

See also page 70

5. The climate should be carefully described, especially with regard to moisture. If no exact register or record has been kept of the rainfall, the seasons of rain, together with the heaviness, frequency, and duration of the rains or dew, should be described as nearly as possible. The occurrence of snow, severe frosts, hoar-frosts, thunder-storms, and hurricanes also must be known; also the effect the climate has upon timber, whether there are destructive insects or vermin, and whether any preservative process for wood can be applied in the country and is likely to be effectual. All the above facts have weight in determining the choice of poles, insulators, and wires, and the methods of attachment. The effect of the climate upon health, so far as it would affect the engineers and workmen who would have to construct and maintain the line, must also be mentioned.

Beasts and vermin.

6. The obstructions, if any, which are likely to be met with from beasts, birds, insects, or vermin.

Population.

7. The population in the districts through which the line would pass; the degree of civilisation they possess; and the restraints, if any, which it will be necessary and possible to put on them with regard to the protection of the line.

8. The harbour facilities which exist for the landing of material brought from England; the port or town dues; and the import duties which may be levied.

Harbour facilities.

9. The means of transport which exist from the port of arrival of the material, or other base of operation to the line of route; and the cost of carriage. The roads for vehicles, or tracks for horses or mules, should be described, together with the facilities for obtaining beasts of burden and forage at all seasons of the year, and at what cost.

Transport.

Horses and forage.

10. The kinds of workmen, skilled and unskilled, which are obtainable, and at what cost. The accommodation for lodging the workmen; and the provisions and fuel obtainable along the route.

Workmen.
See also page 70.

11. The terms of the permission or concession which have been obtained for the construction of the line. Special information must be afforded as to the right of way over roads and lands for erecting the poles, and the protection against damage to the line when laid which will be afforded by the Government or by the law of the country.

Terms of concession.
See pages 24-33.

Legal rights.

12. The terms of payment which it is proposed to make with the contractor or other constructors of the line.

Terms of payment.
See pages 21, 40, 49.

13. The reasons which have suggested the construction of the line to the promoters; the necessity or demand which exists for the new line, and the data upon which the calculations of revenue have been based. In connection with these points, particulars should be furnished concerning the number of inhabitants and their avocations in the terminal and intermediate towns, so far as this information will be a guide to the amount and kind of traffic which may be expected. If the promoters desire to provide for a certain amount of traffic present and prospective, sufficient wires must of course be laid and the poles made strong enough for the additional wires afterwards.

Data for calculating revenue.

14. The terms which have been or can be arranged for the exchange or forwarding of messages by existing lines or cable-routes which the new line is to join. Where the new line is a continuation of, or a branch from, an existing main line, it is most important that access to the capital of a country and to the chief sources of traffic should be obtainable on equitable and remunerative terms arranged beforehand.

Interchange of traffic.

Overhead-telegraphs are liable to damage during heavy wind or snow, or by the contraction of the wire by frost, as either of these

Damage to overhead lines.

Underground telegraphs.

Early trials unsuccessful.

See page 90.

Berlin-Hamburg-Kiel line.

Future improvements.

Conductor-wires.

How made and laid.

events may put such heavy strains upon the wires as to break or force them down. In such a case, not only is telegraphic communication interrupted, but the road or railroad along which the telegraph runs is blocked against traffic by the fallen poles. These risks have directed the attention of engineers to a more extended use of underground wires, which, up to 1877, have been mainly confined to cities. The Prussian Government laid, during 1847–1852, about four thousand miles of guttapercha-covered underground wires; but these wires were not encased or protected by sheathing, and therefore failed. Underground wires were also laid in England, between London and some of the provincial towns, but they were badly constructed and also failed. The great experience which has been since gained in the manufacture of submarine cables renders it probable that if, in regard to underground cables, equal care be bestowed, as well upon the design and choice of materials as on the workmanship, similar success will be attained, and for these reasons renewed attention has been given to the subject. In Germany a multiple-cable, sheathed with iron, was laid in 1875, between Berlin and Halle; and in 1877 a 7-cored cable was laid between Berlin, Hamburg, and Kiel. Underground wires, in pipes, were in 1876–7 being also tried in New York, with the view of substituting them for the poles and overhead wires which disfigure so many of the American cities. There are certain differences in regard to retardation of speed by induction which have to be guarded against; but these will probably be overcome by proper precautions, although up to the year 1877 there has not been much experience in regard to long lines. As underground wires have not—like those suspended between poles—to withstand heavy strains, the strength of iron is not needed, and suitability as a conductor is alone required; but it is necessary that the wire be protected from damage by digging, from the attacks of vermin, and similar contingencies. Light copper conductors of one wire of about No. 18 B.W.G. (=·049 in.), or formed of 3, 5, or 7 strands of 22 B.W.G. twisted together, are generally used; and each of such separate conductors is enveloped in gutta-percha, so as to produce a total outside diameter of about No. 5 B.W.G. (=·22 in.) A bundle of such conductors or—as they appear—cords is, for telegraph lines in cities laid loosely together in an iron trough, or lead pipe, access to which is provided, at intervals of about 100 ft., by openings in the road or pavement, covered with iron doors. The cost of laying underground lines of this kind is in cities greatly enhanced by expenses of paving and by the difficulties of working in crowded streets. From these causes underground lines in London with about 30 wires have cost more than £2,000 per mile. For long country lines it is usual to twist the separate conductors into a cable, to sheath them with iron wires, and to coat them with asphalte; a cable thus constructed being effectually protected from vermin and mechanical injuries.

City lines expensive.

Underground cables.

Before leaving the subject of land-telegraphs, the modern systems of subsidiary pneumatic tubes may be referred to. In London and other large cities, where numerous offices for receiving messages are grouped within a moderate distance of the central transmitting office, these tubes have been found very useful for conveying the written messages to the common centre. The tubes are of lead (which has in London been found hitherto to be better than iron), of about 2½ in. internal diameter; and through these tubes cylindrical carriers, or pellets, are blown or sucked by pneumatic pressure or exhaustion. The carriers are of gutta-percha, covered with drugget, and the written messages are placed inside. This plan has been found much cheaper than that of employing messengers or of transmitting the message for the short distance by the electric wire, besides avoiding the risk of errors in the extra transmission. The cost of such tubes, including the laying in the streets, is from £600 to £1,000 per mile; the exact sum depending, among other conditions, upon the nature of the pavement. The pumping apparatus costs from £1,500 to £2,000, and, if placed at the central station, it can be made available for several lines of tubing in different directions. The addititional apparatus at each despatching station costs about £100. All these amounts are exclusive of the cost of buildings. At the end of the year 1875 there were in London eighteen miles of pneumatic tubes in use, and more were proposed. The tubes were also being used in the principal provincial towns. The pneumatic system is also used in Paris, Vienna, and Berlin; but, when the practice in these cities is compared with that in London, that of the latter city is found to be most expeditious and economical. In connection with the postal service in Berlin there is a complete system of pneumatic tubes for the conveyance of letters from one part of the city to another; letters being transmitted directly they are handed in to a receiving office; the cost to the sender for this service being about three times that of ordinary postage.

Subsidiary pneumatic tubes.

Convenient for short distances.

Cost of tubes and apparatus.

Pneumatic system in Berlin.

Instruments. Batteries, instruments, and the various kinds of apparatus used in connection with electric-telegraphy, are matters of detail, which it is not necessary to treat of here. Out of the great variety of recording instruments which have been invented, only a few of the best types have been permanently adopted and are now in use. Recent invention has been directed towards the acceleration of traffic, and some of the improvements so effected are most ingenious. **Automatic instruments.** By improved automatic instruments, a maximum of three hundred messages per hour can be transmitted on short lines, although, in practice, two **Rates of speed.** hundred messages per hour is usual; while on longer lines, such as from London to Dublin, only fifty messages per hour are transmitted. **"Repeaters."** By means of automatic "repeaters," messages can be sent forward from one section of wire to another, without the necessity of effecting all from one terminal battery. In England, messages are in this way sent by the one initial operation from London to the extremities of **Punched tapes or ribands.** the island. By punching on paper tapes or ribands, perforations which represent letters and words, and by reproducing these tapes in sufficient numbers, Press or other long messages can be forwarded from one central office in different directions at once. The tapes can be punched at the rate of from thirty-five to forty-five words per minute; and four of the ribands are frequently punched simultaneously, thus augmenting the number of punched messages. **Automatic printing.** Automatic printing instruments record messages in ordinary type at the rate of about fifty words per minute.

The duplex system. One of the most important additions to telegraphic signalling has been the re-introduction of the "duplex" system, by which messages can be transmitted in both directions, through the same wire, at the same time. The improvements which have (1877) been effected, so as to render the duplex system practically available, make it probable that it will be largely adopted in the future.

Submarine telegraphs. Submarine telegraph-lines are pre-eminent amongst the modern wonders of the world. The first submerged cable in salt-water was successfully laid from Dover to Calais in 1851, and after three attempts, all more or less failures, in 1857, 1858, and 1865, to cross the Atlantic, submarine telegraph communication between Ireland and America was achieved in 1866, and has since been maintained. When telegraph-lines are laid under water, conditions very different from those pertaining to land lines have to be satisfied. The mere insulation and protection from the water could be effected without

Cables without sheathing.

the elaborate cable-structure which is generally adopted. Thus the submarine line which was laid successfully in 1855, during the Crimean War, betweed Varna and Balaclava, a distance of 300 miles, consisted of a single copper wire, No. 16 B. W. G. (=·065 in.), covered only with gutta-percha, the outside diameter being about $\frac{5}{16}$ in. This cable, though not made in the perfect manner which has since been attained, worked successfully for about nine months.

Strong cables necessary.

But other exigencies have to be met. Just as the wire of a land-line has to be made strong enough to withstand the heavy strains of suspension and of the wind, so has the submarine cable to satisfy conditions also entirely outside those of the electrician. A submarine cable must be made strong enough to sustain its own weight, and the other strains to which it is subject while it is being laid or picked up; and it is obvious that the greater the depth of water the greater will be the length, and therefore the weight of the bight. But if the tensile strength be increased by giving more or thicker sheathing-wires, the weight is again increased, and so the two opposing circumstances grow together. The effective weight of a cable is of course less when submerged than when above water, and cables can be constructed with few or light sheathing-wires, which weigh very little when submerged. The real danger lies in the strains from the vessel from which the cable is being laid or picked up; and even when great care is exercised, it is sometimes impossible in a rough sea or in a gale of wind to prevent considerable tension on the cable as it is passing over the stern or when being picked up. Indeed, unless sufficient precaution be taken, the vessel is in effect sometimes anchored to the cable, with consequences that may be anticipated.

Cables liable to severe strains.

Damage from anchors.

Submerged cables are subjected also to the risk of damage from ships' anchors, and this risk is of course greatest in shallow waters and much frequented seas; therefore cables which are laid in such situations have to be made much stronger than those for deep ocean service. Thus, while the weight of a deep-sea cable will range from 1½ to 3 tons per mile, for such situations as the English Channel a weight of from 4 to 6 tons per mile is considered necessary: the greater weight being reached when the cable contains more than one conductor. As the cable approaches the shore the danger from anchors is increased. Moreover, the cable is then exposed to the surf, and is liable to be chafed on rocks or shingle; therefore

Shore-ends of cable.

Boring shells.

the shore-ends of cables are made exceptionally strong, a weight even of from 15 to 20 tons per mile being occasionally attained. In waters where the boring shells (*teredo navalis*) or worms are exceptionably destructive, sheathing-wires are insufficient, and the cable must be enveloped in copper strips if it is to be long preserved.

Improvements in cables.

Certainty of success.

Continual tests necessary.

So many cables have been laid, and so much experience has been gained under what would appear to be every possible combination of circumstances, that all the incidents of manufacture, laying, picking-up, and repairing, are known to those concerned in such enterprises. Consequently, instead of the very great uncertainty which at first existed, telegraph engineers will undertake the laying of a cable, confident that, whatever be the accidents of the operation and the cost, they will finally succeed. But the amount of money invested is so great, and the interests at stake are so momentous, that too much care cannot be exercised in the design and manufacture of the cable in the first instance. Not only must the cable be capable of transmitting messages, but its electric condition must be such as to do so with the greatest speed, so that by taking the maximum number of words it can earn as much as possible. Every material used in its construction has to be carefully selected with regard to the necessary qualities; and the continuity and insulation of the conductor have to be tested through every stage of its manufacture.

Conductor-wires.

Insulation.

Each conductor is generally composed of several copper wires twisted together into one strand, instead of one solid wire as in a land-line, as by this means is neutralised the effect of fracture in any one wire, which, though of comparatively small consequence in a land-line, which can be easily repaired, would be serious in a submarine cable, necessitating in the case of deep-sea cables a costly repairing expedition. In regard to insulation, the manufacture of submarine cables has (1877) been brought to such perfection, that no immediate improvements are looked for. The more recent cables of the Atlantic, Indian, Australian, and other lines have in this respect surpassed all that was expected of them.

Description of cable.

Cables differ in their size and exact arrangement, but usually each conductor is enveloped in gutta-percha, somewhat in the same way as are the underground wires previously described on page 86. A cable contains one or more such coated wires, as many as seven being often employed. The longer the cable, the greater is the resistance it offers to the electric current, and the ordinary ink-recording or needle instruments in use on land lines are not sensitive enough for signalling through long cables. For the Atlantic cables two kinds of instruments are in use, viz. the "mirror" instrument and the syphon ink-recording instrument. In the former, a small mirror, suspended by a cocoon fibre, is deflected by the current, and the rays of a lamp placed opposite to the mirror are reflected by it on to a scale; the combination of the movements of the bright spot on the scale denoting the letters. The syphon-writer is a very delicate instrument, in which a fine glass tube, acting like a pen, traces the signal on to a moving paper strip or riband. By these means the effect of the current is utilised to the utmost, and the necessary battery-power kept as low as possible. Although the time actually occupied in transmitting each separate signal is even in the longest cable very short, still the signals become less defined and separable as the length increases. To meet this, a greater interval must be left between each signal, and therefore in long cables the number of words per minute is much less than with short lines. Thus, while forty words per minute can be transmitted from London to Paris, eighteen words is (1877), even with the latest and most perfect cable and instruments, the limit between Ireland and Nova Scotia; and these circumstances must obviously be taken into consideration when choosing the number of conductors and kind of cable to transmit expected traffic. But although it may prove cheaper to lay one cable with two or more conductor-wires than two cables each with one or few wires, it must also be remembered that a duplicate cable tends largely to ensure a regular revenue which an accident to a single cable would stop entirely. For long ocean-lines more than one conductor renders the cable too heavy.

Instruments.

Mirror and syphon-writer instruments.

Speed of transmission.

Number of words per minute.

Duplicate cables.

For laying across rivers, bays, or estuaries, not much special preparation is necessary. In shallow waters a cable can be best laid by men wading and carrying it from hand to hand: where this is impossible, vessels or large boats can be employed for the purpose. In inland seas a sailing-vessel towed by a steamer can be temporarily equipped as a telegraph-ship, but there is always more risk in such cases than where a proper steamer is used. A towed vessel does not steer well, especially in rough weather, and cannot be stopped quickly in case of fault. Cables have, however, been successfully laid for considerable distances by such means when no proper telegraph-steamer was available. In the case, however, of an ordinary iron steamer used temporarily for such service, the great cost of altering

Methods of laying cables.

Telegraph-ships.

it to make tanks for the cable and for other necessary arrangements is a reason in favour of employing a wooden vessel, which can be altered more cheaply.

Contractors for cable-laying.

But although there are contractors and companies who, for a stipulated price, will undertake to make a suitable cable, and to lay it safely, taking all the risk of accident and failure, the price charged for such a service is based upon the very heavy expenses incident to it, and also upon the probabilities of loss as estimated by previous experience.

Cable-laying machinery.

The machinery and equipments of vessels, specially constructed for laying and picking-up deep-sea cables, have been brought to great perfection; and as a result of dearly-bought experience, such vessels and machinery can be employed with a certainty of ultimate success. But although a considerable number of engineers have now acquired experience in the laying of cables, the number of properly-equipped vessels is small, the cost of maintaining them very high, and when in actual work the salaries, wages, and insurance special to the enterprise add enormously to the expenses—never very small—which are always incident to the voyages of steamers. And when a cable has to be laid in a distant sea, the time occupied and the distance from supplies add greatly to the cost of an undertaking, which, as has been shown, is in any case an expensive one. The contractors for such works naturally require in return a high rate of profit. The expenses of a fully-equipped telegraph steam-ship, including coal, stores, wages, salaries, insurance, and interest on capital, will range from £5,000 to £8,000 per month, according to the size of the vessel and the exact nature of the service. And to this expense must be added not only the profit of the contractors on the capital embarked in the construction and maintenance of such a vessel, but, if they have undertaken, as is generally the case, the responsibility of laying the cable successfully, an additional sum, which may be considered as a premium of assurance against loss.

Costly steamers.

Expenses during laying of cable.

Corrosion of sheathing-wires.

The corrosion of the outer wires, which is more or less rapid in different situations, is perhaps the chief defect in the ordinary type of submarine cable. To meet this, the plan of protecting the outer wires by another covering has been tried. The cable as a whole, or each outer wire of the cable separately, is served with one or two layers of tarred hemp, or jute, and, when required, the cable is finally covered with a coat of bituminous compound. This plan has been adopted in most cables, where an outer covering is tried at all. But apart from this liability to rust, cables, where undisturbed, seem to

Cables coated with bitumen.

last a long time. The line between Spezzia and Corsica, laid in 1854, was in 1876 in good working order. Experience like this greatly encourages telegraph enterprise, as it proves that a cable properly made and laid has life long enough to amply repay its cost.

Fluctuations in cost of cables.

The cost of telegraph-cables, of course, varies according to their size and kind, but it is also subject to fluctuations, not usual in most other manufactures. Although the cost of all articles varies with the value of the materials of which they are composed, it is not often that so many circumstances have to be taken into account as with submarine cables. Copper, hemp, gutta-percha, and iron are the materials used for cables, and the current prices for each of these are determined by causes differing in each case. It may be said, generally, that the cost of cables has diminished, partly because of the skill and experience that have been acquired in all the processes of manufacture, and partly because of the greater competition which now exists. The approximate cost of submarine cables in 1877, exclusive of the cost of laying, may be given as from £100 to £500 per mile.

Cost of cables per mile.

Cost of single-conductor cable.

A submarine cable of the most recent kind, with one conductor composed of seven No. 22-gauge copper wires, twisted into one strand, covered with three coatings of gutta-percha and one of compound, served with yarn, sheathed with twelve galvanised-iron wires of No 9 gauge; finally served with two layers of tarred yarn, and bituminous compound, the cable having an outside diameter of ¾ in., and weighing about 3½ tons per nautical mile, would cost from £100 to £150 per mile, according to the prices current at the time for the various materials used. The shore-ends and intermediate portions would have conductors and coatings similar to the deep-sea portion, but with sheathing-wires adapted to the nature of the sea-bed, exposure to anchors and other circumstances; the weight per mile being increased to between 6 tons and 18 tons per mile. The extra price per mile (in addition to that for the deep-sea portion) would be from £25 to £40 per ton of extra weight.

Cost of shore-ends.

Cost of 3-conductor cable.

A submarine cable with three conductors, each made and insulated in its own coatings, as in the cable just described; the three insulated conductors stranded together and served with yarn, sheathed with galvanised-iron wires, and finally served with two layers of tarred yarn and bituminous compound, would have an outside diameter of from 1¼ to 1½ in., and a weight of from 7 to 10 tons per mile, depending on the sheathing-wires, the strength of which would be determined by the risks to which the cable was to be exposed. The deep-sea portion, which would be used for ocean routes and unexposed seas, would cost from £200 to £300 per mile, while the shore-ends and intermediate portions would be heavier and more costly, as described for the single-conductor cable.

Cable ventures speculative.

Risks of maintenance.

Sinking-fund.

Cable Trusts.

For any but a short and easy line, a submarine telegraph is a very speculative undertaking, and one in which the compensating revenue must be tolerably certain to justify the investment of capital. Different investors prefer different kinds of ventures, and hence that of making and laying a cable is kept separate from that of the ownership of the cable when laid. The telegraph-company which employs the constructors to lay as well as make a cable, have obviously to pay for their services and risks, although they have the satisfaction and protection of knowing beforehand how much they will have to pay. But even where a submarine telegraph has been successfully laid, it is still in an entirely different position from a land-line. A land-telegraph, if well constructed, need cost but little for maintenance, and the proprietors may be contented with moderate traffic at the commencement if there is a probability of increase; but a submarine line should pay handsomely from the first if it is to satisfy the expectations which alone will justify the investment of capital. The cable may fail at any moment; its life is limited, and the cost of renewal is great. In fact, to make such an undertaking any better than a lottery, and to put it on a stable basis, a duplicate line should be laid. It is evident, if the above considerations be true, that a large proportion of the annual revenue—especially when there is only one cable—must be reserved either for maintenance, or as a sinking-fund, before the revenue can justly be applied to dividend. To reduce as far as possible the risks peculiar to such enterprises, special "Trusts" have been formed, by which the capital of investors is divided over several different cable undertakings.

Private enterprise.

See FACILITIES *and* IMMUNITIES, *page 25.*

Submarine cables of moderate length for connecting two parts of the same country, may naturally form part of one general national telegraph system, of which land lines may form the other and perhaps greater part. Where, however, the Government or other owners of the land-lines are unable or unwilling to lay a submarine cable, the undertaking affords a legitimate opportunity for private enterprise. In the case of international cables, there are but few instances of the Government of a country doing more than afford permission or encouragement to private capitalists. Assistance or encouragement may be given in any of the various ways previously referred to, or privileges in regard to the connection with existing or contemplated land-lines may be granted. In some cases an absolute monopoly has been conceded, which excludes all other cables from being landed; but such a concession, as being against public policy, is rare. The co-operation of numerous capitalists, through the medium of joint-stock companies, is the almost invariable method of conducting these enterprises, which are too speculative to justify large individual outlay.

See CONCESSIONS, *Chap. II.*

MONOPOLIES, *page* 27

Information on which to base estimates.

The following information is that which is necessary to enable a telegraph engineer to decide on the most suitable kind of cable, to allow contractors to estimate the cost, and capitalists to calculate how far the enterprise will be remunerative;—

Chart of route.

1. A map, or chart, showing the places between which the cable is to be laid, and showing any existing cables which must be avoided.

Depth of water.

2. The depth of water will probably be approximately known from the soundings marked on existing charts; but it is necessary to take special soundings, not only to ascertain the depth of water, but to discover the nature of the sea-bed. Abrupt alterations in depth are to be avoided, as also is a bed of rocks, or boulders. The regular tracks of passing vessels which may approach or intersect the line of the cable, should be indicated, and any other particulars by which the liability to damage from ships' anchors may be estimated. From the information thus obtained, the route which offers the most favourable conditions can be chosen. Such conditions are a level or undulating bed, composed of mud, ooze, or sand.

Nature of sea-bed.

Landing-places.

3. Places favourable for landing should be surveyed and described. A sheltered bay, a cove, or estuary, with a sandy beach, and out of the way of anchoring vessels, is the sort of place to be chosen. It is desirable to choose such a place, even if not in the direct line, for if an increased length of cable or land-line is rendered necessary, the expense will be amply repaid by the safety afforded to the cable.

Suitable seasons.

4. Information should be furnished as to the seasons of the year most favourable for laying the cable, and as to the currents, tides, and winds which usually prevail.

Connection with land-lines.

5. The land-lines with which communication must be made should be indicated on the map, and the terms on which the transmission of cable-messages and exchange of traffic over such lines will be allowed.

Amount of traffic.

6. The amount of traffic which is to be provided for.

CHAPTER VI.

HARBOURS AND DOCKS. LANDING-PIERS AND JETTIES.

The necessity for harbours.

As the population and the trade of the world increase, facilities for intercommunication acquire enhanced importance, and to those countries and districts which are bounded by the sea, safe harbour accommodation becomes absolutely necessary. Generally, large centres of population, commerce, and manufactures are situated upon the banks of rivers which serve as ports of entry from the sea, or on the sea-coast itself; and to these centres the great railways and roads naturally converge. In colonies and new countries, river improvements and harbour construction should be undertaken simultaneously with the formation of railways, or at any rate the internal communications and the openings to the sea should be held in view together, even if the works are not carried out at the same time. Many a harbour, either practicable by nature, or easily to be rendered so at moderate cost, is unused because the roads or railways inland do not accord; and perhaps when it is attempted to make use of natural advantages, the vested interests of existing, even though inferior harbours whose trade is supposed to be threatened, may prove too strong, and may stifle the new enterprise. The natural commerce of a country is greatly checked if safe and commodious harbours be wanting; and their construction is a public work of the first importance. Where vessels have to anchor in an exposed roadstead; where the entrance to a river is rendered difficult of ingress and egress by a bar, or where rocks or shoals obstruct a harbour mouth, the risks incident to such defects have great effect in restricting commerce. Merchants and shipowners have to pay for these risks either by high rates of insurance, or in the precautions necessary for safety; and in either case the commerce of such a port is greatly weighted in its competition with that favoured by a convenient harbour. A sheltered

Natural harbours.

Commerce checked if harbours be wanting.

Bars, rocks, and shoals.

anchorage, a safe harbour of refuge, or one offering facilities by floating-docks or graving-docks for quick despatch of cargo, or for repairing vessels, will benefit not only what may be called the natural trade of the port, but will tend to make the harbour a port of call, and perhaps even make it an entrepôt of a widely extended trade. So much are these considerations recognised, that the Government or Legislature of a country generally consider it one of their duties to encourage, even if not to undertake, such works; and so important is it that unity of purpose and broad national interests should alone be allowed to prevail, that the promotion of such public works by the granting of concessions to private capitalists, should be permitted only when the above considerations have been allowed to have their proper weight.

Harbour facilities promote trade.

National interests.

In Great Britain, Parliament has authorised from time to time a large expenditure of national funds for harbours or breakwaters useful for the navy, or which may be considered as of national rather than of local importance. The magnificent harbours of Portland, Holyhead, Plymouth, and Dover may be cited as examples. Works of this kind have been carried out in different ways. Sometimes the whole is managed by Government engineers without the employment of a contractor; while in others, contracts are made either for all or —from time to time—for portions of the work. A large amount of harbour and dockyard construction, both in England (as at Chatham and Portland) and at English naval stations abroad (as at Gibraltar and Bermuda), has been performed by convict labour, and provisions for such service are occasionally included even in the agreements with private contractors. The estimated outlay for harbours has often been exceeded; the results have not always been favourable; and there has been a growing disinclination in successive Parliaments to vote money for such works. The more recent harbour works have been in connection with commercial ports, and the expediency of granting State aid to such undertakings has been strongly urged both in and out of Parliament. Such aid has, however, been almost invariably refused, and the tendency has been rather in the direction of permissive legislation, which sanctions the borrowing of money by local authorities, and allows rates or tolls to be imposed for meeting the interest on such loans and for repaying the principal. Numerous Acts of Parliament of the nature of private Bills have been passed for commercial harbours and docks, and in some instances State aid has been afforded in the shape of advances from the public funds, to be

Expenditure for harbours in England.

Convict labour.

Disinclination of Parliament to vote money.

Government aid refused.

Permissive legislation.

Borrowing powers granted.

Private Bills for harbours.

See PARLIAMENTARY PROCEDURE.

Public Works Loan Act.

Loan Commissioners.

Loans confined to national harbours.

Reports by Government engineers.

repaid with interest in a term of years. A general Act, intituled the Public Works Loan Act, specially intended for harbour, sanitary, and similarly beneficial undertakings, authorises such advances; but the Public Works Loan Commissioners, who—subject to the control of the Government of the day and of Parliament—administer the funds, confine the loans strictly to cases where the harbour works have a more than commercial value; and pecuniary assistance is therefore refused unless the works appear likely, as harbours of refuge or adjuncts of fisheries, to be a national benefit. Even under these conditions advances are made only after reports from Government engineers that the intended works and the estimates of cost are sufficient for the purpose in view, and that enough revenue will be forthcoming to repay the loan.

Provisional orders of Board of Trade *See also page 9.*

Although for all harbour works of magnitude, authorising Acts of Parliament are necessary, small undertakings are, where there is no opposition, carried out without the trouble and expense of a special private Act under the Provisional Orders of the Board of Trade already described.

Local expenditure for mercantile ports.

Works made remunerative by tolls.

Modes of levying tolls.

Capital, how provided.

Where the improvement of a harbour, or the construction of a dock, is required for the special interests of a mercantile port, the works may be constructed and paid for by local or municipal capitalists if the expenditure be within their means; but in the majority of instances outside aid has to be sought. In such cases the advantage to the town and to the mercantile community, which may be expected to accrue from the proposed works, may be sufficient of themselves to justify the undertaking. But generally it is sought to make the works directly remunerative by subjecting vessels, merchandise, and occasionally also passengers, to a tax or toll for the use of the improved accommodation. The revenue from harbours and docks is generally levied in the shape of dues on vessels calculated according to tonnage or draught; on merchandise according to weight, bulk, or value; and on passengers according to number. It is, as has been said, only where the present or expected trade of the port warrants expectations of a revenue sufficient in proportion to the cost to prove directly remunerative as a separate undertaking, apart from the indirect advantages to the town or country, that capitalists will be found willing to embark in it without special security. In such case the money may be provided either by share subscription, through the ordinary means of a Joint-Stock Company, or by means of a Harbour Trust. In the former case the net revenue will be applied to the payment of a dividend to shareholders, who, as in the case of joint-stock undertakings generally, will naturally endeavour, by keeping down expenditure and maintaining high rates, to obtain as much profit as possible. In the latter case, the money is raised on bonds bearing a fixed rate of interest, for the payment of which the revenue of the undertaking is pledged, the profits beyond what is necessary for this fixed rate being applied to the extension or improvement of the works, sometimes also to a sinking-fund for the redemption of the bonds, and then to the reduction of the tolls. It will be seen that the joint-stock method is the one most favourable to the speculative investor, while the harbour trust is most conducive to the interests of the port or town. But as, according to the latter system, the stimulus to good management which the self-interest of shareholders affords, is wanting, there is some of the risk which always attends corporate undertakings of inert or corrupt management. The appointment of capable trustees of high standing, of energetic managers, and the publicity of accounts, are the best safeguards against these risks. The joint-stock companies who own the Docks of London, Southampton, Hull, and Plymouth, afford examples of the one system; and the Clyde Trust, the Mersey Docks and Harbour Board, the Dublin Board, the Belfast Board, the Bombay Port Trust, and the Calcutta Port Trust, are examples of the other system. The lower the dues, the more inducement there is to use the port; and sometimes it is so much to the interests of the town or country to attract vessels, that the port is made entirely free, and dues are charged only for services actually rendered in the shape of pilotage and craneage; with sometimes small dues for lighthouses and wharfage accommodation.

Joint-stock undertakings and harbour trusts.

Sinking fund.
See page 37

See also page 166 WATER-WORKS.

Dock Companies.

Harbour trusts.

In foreign countries, where there are not the same facilities as in England for obtaining money from private capitalists, the Government has to assist either by subsidies, guarantees, or concessions. A harbour or dock may form the subject of a concession granted to those who will furnish the capital and perform the works; certain rights will then of course be demanded, and the various kinds of engagements under which the works may in this way be undertaken have been already described. The concession may grant either mere permission, or facilities, or subsidy, or monopoly, or guarantee; and the precise terms of such engagements are of course a matter for special arrangement in each particular case.

Foreign harbour works.

Concessions.
See Chapters II. and III.

See pages 26—33.

Harbour engineers.

Specialists.

Whatever be the financial conditions on which such works are undertaken, the assistance of a competent engineer is of course necessary. In England, as elsewhere, there are engineers who have made the construction of harbours and docks their especial study; and amongst such specialists, there are some engineers who stand pre-eminent, and whose works of this kind, carried out in all parts of the world, remain as standing examples of English energy and skill.

Natural harbours requiring little alteration.

Difficulty of estimating cost.

Contracts.

Works carried out without contractors.

Contingencies.

Some of the finest harbours in the world are those provided by nature, and even where not complete, they in many cases require little alteration to render them commodious and safe. The removing of a few rocks, the dredging of a channel or basin, the extension or alteration of a natural breakwater, the construction of a jetty or quay, may be all that is needed; and such works may often be carried out at a comparatively moderate cost. Even where expensive works will eventually be needed, a moderate outlay in the first instance for protective works may so encourage and extend trade as to provide funds later on. In other cases the works may be of such magnitude, or so difficult, that only contractors with exceptional resources or ability can venture to attempt them. The difficulty of estimating exactly the cost of projected harbour works often renders it impossible to make satisfactory contracts for the whole undertaking, and separate contracts must be made from time to time as the works proceed, or the works must be carried out directly under the supervision of the engineer without the intervention of contractors. In colonies or distant countries this course is in many cases expedient, even where not absolutely necessary; for where only few contractors are able and willing to tender, and where unknown contingencies have to be provided for, contractors' estimates will often be much higher than the actual expenditure which need be incurred by the superintending engineer.

Choice of sites for harbours.

Quarry space utilised.

As a rule, bays and indentations of coast-line offer the best sites for harbours, and in such cases advantage should be taken of the shelter afforded by natural headlands, to enclose the greatest area of deep water within the works. Provision may sometimes even be made for utilising the quarry space, from which the stone is obtained for forming the sheltering breakwater or pier, by subsequently converting it into a floating basin, as was done in the case of the harbour and dock works constructed at Table Bay, Cape of Good Hope.

River ports. Rivers afford the readiest, and on the whole, perhaps, the most satisfactory sites for trade centres; but they have their drawbacks in the shape of swift currents as well as of bars and shoals, which not unfrequently require costly remedial and corrective works, in order to render navigation constantly practicable. **Remedial works.** The deepening and regulating of rivers, therefore, may be included amongst harbour works. Rivers with wide estuaries flowing through a flat country into the sea, have a diminished velocity as their area extends, and the alluvium, sand, or other solid matter held in suspension is deposited at the bottom of the stream, forming thus deltas, and—by the combination of the tide—bars also, which greatly obstruct the navigation. **Deltas and bars.** Examples of this are afforded by the deltas of the Nile, the Thames, the Danube, the Rhone, and the Mississippi, and in these cases artificial works of great magnitude are necessary to clear away the obstructions, either directly by dredging, or by removing the cause of them, and preventing their recurrence. Where the mouth of a river appears hopelessly obstructed, artificial canals are sometimes cut to the sea, as on the Nile and the boat canals on the Rhone. **Artificial canals.** In other cases, such as the Thames, banks or sea-walls are built, to confine the river to a narrow course, thus also reclaiming large tracts of land for tillage; **Banks and sea-walls: *See* RECLAMATION.** as a third method, by building piers at the river's mouth to narrow the channel and accelerate the current, as has been done successfully at Tynemouth; or, again, by the construction of training-walls, dykes or levees (not necessarily higher than the surface of the water), which, by narrowing the real channel, increases the velocity of the current and diminishes the deposits. This plan has been carried out with great success at the principal navigable mouth of the Mississippi. The theory by which these operations are justified is to some extent explained by an opposite case, where a river flowing between high banks into the sea retains to the last its velocity of current. Dartmouth Harbour, in Devonshire, affords an example of this kind, **Dartmouth Harbour.** the river Dart (which forms the harbour near its mouth) flowing into the sea between steep and rocky shores. The Dart has no bar, although it brings much inland water with alluvium in suspension to the sea.

Marine structures difficult. There is probably no branch of engineering science which presents so many difficulties as that which deals with marine structures. Difficult or all but impossible, however, as some proposed harbour works may appear, the facilities afforded by modern science are almost un-

Aids afforded by modern science.

limited; and in battling with the winds and waves, there are modern mechanical devices and helps available, of which the following may be specially mentioned as important, viz. Concrete or *béton*; Dredgers; special Steam and Hydraulic machinery; Diving apparatus; and improved Explosives.

Concrete and béton.

See PORTLAND CEMENT *in Part II.*

It may be truly said, that the introduction of Portland cement, and of the improved concrete or *béton* which its use affords, have revolutionised the art of marine construction. In the earlier construction of harbours and breakwaters, great expense was incurred in the working and carrying of blocks of stone; and very frequently all the efforts of the engineer in this respect were nullified by the destructive force of the waves. Now, the materials for manufacturing concrete are brought easily, expeditiously, and cheaply to the site, and are there either deposited *in situ*, or are formed into huge blocks, which presently become as hard and durable as stone. In the earlier employment of this material by the French engineers, blocks of ten to fifteen tons were deemed large: now, blocks of thirty tons are tossed into the sea by the thousand, and others of all sizes up to, or even beyond, 300 tons in weight are built, conveyed, or deposited wherever they are needed. It may almost be said that the power of the waves has in this respect at least been conquered, for although in a few specially exposed situations the heaviest blocks have—as at Wick, in Scotland—been shifted, breakwaters and sea-walls can now be built of a strength and durability never possible before. The engineer to the Dublin Ballast Board has successfully constructed the underwater portion of a sea-wall on the river Liffey by means of blocks of rubble masonry, each weighing 350 tons, which were built on a working floor, and afterwards placed in position with the greatest ease and nicety by a highly ingenious floating shears, which he designed for the purpose. Blocks of concrete each of 100 tons in weight have been (1876-7) employed to form the foundations of a breakwater at St. Helier's, Jersey; and at the Aberdeen Harbour Works, continuous walls or masses of concrete have been formed *in situ*.

Large concrete blocks.

Continuous homogeneous walls of concrete.

Continuous homogeneous walls can be cheaply constructed of concrete, for dock, quay, or other walls, in cases where, if stone or brickwork alone were available, the high cost would forbid the work altogether. Hollow cylinders of concrete have also been substituted with economy for iron cylinders in the foundations of river walls, on the Clyde and the Thames. There would appear to be practically no limit to the variety of uses for which this com-

Concrete cylinders.

See also page 118.

paratively modern constructive material may be successfully employed, where ballast or other substance for concrete is plentiful.

Dredging machinery.

See DREDGERS *in Part II.*

The improvements which have been effected in dredging machinery during the ten years ending 1877, have greatly facilitated harbour work and river improvements. The cost of dredging, and of depositing, have been so much reduced, that instead of the training-walls and groynes formerly considered necessary for directing the current so as to scour and deepen the river-bed, it is now, in many cases, cheaper to dredge away the banks or deposits which obstruct the tidal flow, and by periodical dredging to maintain a navigable channel. In the majority of cases, the sea is available for depositing the dredged material, which can be conveyed either by steam hopper-barges, or in hopper-chambers formed in the dredger itself. The remarkable improvements effected in the rivers Clyde and Tyne are the results of judicious and extensive dredging, combined with the removal of inconvenient bends in the rivers' course.

Hopper barges.

Hydraulic machinery.

See CRANES *in Part II.*

The modern improvements in hydraulic machinery have nowhere been more successfully employed than in the mechanism of dock gates and cranes, in regard to which there is now hardly any limit of size and weight. It is of the greatest importance in docks and harbours to provide the most expeditious means of loading and discharging steamers: steam or hydraulic cranes are therefore indispensable, and experience has shown that to meet the varying positions of the hatchways of different steamers, cranes, whether steam or hydraulic, should be movable, except those intended for only occasional use in lifting very heavy weights.

Cranes for quick despatch of vessels.

Diving operations.

See DIVING APPARATUS *in Part II.*

The facilities with which diving operations may now be carried on, whether by cylinders with air-locks, or with the more general diving-dress and bell, admit of the adjustment of work under water within certain limits of depth with the greatest nicety. Thus, for instance, the construction of breakwaters below low-water has been much facilitated, as material can now often be applied with more economy and effect in those situations where formerly vast quantities of stone had to be tipped into the sea, so that the slope of the breakwater might be finally arranged by the waves. The advantages of the "long slope" and the "vertical wall" systems of construction are now better understood, and can be more easily compared, than formerly; but in estimating the cost of projected works, it is very difficult to make a fair comparison with previous undertakings, even of an apparently similar kind. The depth of the water, the frequency of rough weather which may limit the hours of working, and the contiguity of suitable materials for concrete, are among the secondary incidents by which the actual cost is determined. The range of expenditure is very great: in inland or sheltered seas, where the circumstances enumerated above are favourable, sea-walls or breakwaters have been made at all rates, from £30 to £100 per lineal foot, while for large breakwaters in exposed situations, such as Portland, Dover, Plymouth, Holyhead, and Cherbourg, an expenditure of from £100 to £350 per lineal foot has been incurred.

Cost of breakwaters.

Steam-drills and diamond rock-drills, and the improved explosives, dynamite and lithofracteur, all act as aids to the accomplishment of sub-aqueous operations.

Rock-drills. *See also in Part II.* **Explosives.**

But with all the aid afforded by these modern inventions, the ingenuity of engineers and contractors is taxed to the utmost to devise means of overcoming new difficulties. Unlike railway and similar works, it is almost always necessary in sea work to devise special tools or plant, adapted to meet the exigencies of each particular case. Temporary staging may be needed, and yet staging, owing to the force of the waves, or the nature of the sea-bed, may appear impossible. Dredging may be necessary, apparently of insurmountable difficulty; weights may have to be lifted beyond the power of any existing crane. Perhaps nowhere is the application of mechanical contrivance to constructional work better exemplified than in the special cranes, or setting-machines, used in harbour works, where, with an overhanging arm of fifty feet, blocks of thirty tons and upwards are deposited anywhere within a traverse of seventy feet in width. By means of an overhanging crane (sometimes called a "Titan") the breakwater at Kurrachee was advanced 700 feet in less than four months; and the same appliances were afterwards used at the Madras harbour works. At Alexandria, two miles of detached breakwater, composed of twenty-ton concrete blocks, were constructed, tipped with native stone, in less than two years.

New difficulties.

New machinery devised.

Concrete setting-machines.

The construction of Docks may be considered as subsidiary to the greater works of harbours, but the increasing shipping trade of the world is rendering them in most countries hardly less necessary for the purposes of international commerce. In countries like those bordering on the Mediterranean, where there is little or no tide, basins and quays open to the sea may alone be necessary, but in those countries where the rise and fall of tide are considerable, or

Docks.

the flow of water rapid, docks with systems of locks and gates are needed. In the case of rivers where the lift of tide is not great, vessels may be accommodated alongside the river walls, as at Glasgow, Newcastle, Belfast, and Dublin, the necessity for dock works not being felt until the shipping traffic has increased beyond what the river frontage can receive. In England, the docks of London, Liverpool, Hull, Grimsby, Cardiff, and other of the principal ports, afford examples of engineering enterprise and skill, second only in extent and value to railways, carried out by private capitalists.

Examples of modern docks.

Information necessary.

The following information, *inter alia*, is necessary to the design of harbour works, and it will be seen that the particulars described are mostly matters of fact, which can be ascertained by local engineers or surveyors. Promoters of new harbour works will generally save much time and money if, when seeking the advice of an experienced engineer, who devotes himself specially to such undertakings, they are able to lay before him, if it be only approximately, the information now to be described. On the basis of such information the salient points of a design will probably present themselves at once to the engineer, and if not able without more inquiry to propound a complete scheme, he can generally give useful preliminary suggestions as to method and cost; and will be able to select at once, with a view to a complete elaboration of his ideas, those out of a multitude of facts which demand fuller investigation and inquiry. The engineer will also be in a position to afford such information to contractors as will guide them in tendering for the works; and also such particulars as will form a basis for considering the financial merits of the scheme, and the extent to which it is worth the attention, or should command the assistance, of capitalists.

Particulars classified.

The information required is as follows :—

Charts and soundings.

1. A survey or chart of the coast at and near the site of the proposed harbour or docks, including a complete set of soundings.

Tides.

Nature of sea-bed.

2. The maximum rise and fall of tides; the nature of the seabed as ascertained by borings, with any corroborative information obtainable as to strata near the shore; the suitability of the bed for dredging, pile-driving, building, and anchorage. As the character of the proposed works may be determined from this information, the above particulars cannot be too full or precise.

Quicksands and currents.

3. The existence of any quicksands, travelling-shingle, or sand in suspension, and the direction of the tidal or river currents should

be noted; and the movements which have taken place in preceding years should be described, as well as any advance or recession of the sea line.

Winds and seasons.

4. The prevailing winds and the lines of greatest exposure should be described, as well as the nature and effect of hurricanes which have been known to occur, and (in the case of a bay or gulf) the length of "fetch" from head to head, or point to point. The winds, seasons, or tides most favourable to entering or leaving the river, or existing harbour, and the reasons which may have suggested new harbour works. The proportion of fine to rough weather which is usual in the year, so far as it may determine the number of working days for sub-aqueous operations. Information, such as can be obtained from local pilots, as to vessels making and leaving the harbour or coast. The distance to which it is desirable that harbour lights or beacons should be visible.

Information from pilots.

See LIGHTHOUSES *in Part II.*

Draught of vessels.

5. The build, tonnage, and draught of vessels, which are to be accommodated in the harbour; the harbour facilities already existing; the manner adopted for landing goods.

Map of town and approaches.

6. A map of the town or buildings which exist, or are to be built, near the harbour, with the levels of such roads, railways, rivers, or canals as would have to be considered in arranging the landward approaches to the harbour.

Obstructions to foundations.

7. The presence of rocks, boulders, old foundations, or other obstructions to piles or stonework, should be indicated and described. The kind of vehicles which will come upon the quays or piers, with the amount of their loads, and, if railway lines are intended, the weight and size of the engines and rolling stock. The descriptions of goods which will have to be landed or shipped, so far as this may affect the number and kind of cranes or other machinery.

Traffic on quays.

See LOADS ON BRIDGES, *and in Part II.* CRANES.

Systems of dredging.

8. The system of dredging, if any, which may have been used in the locality, and with what success; and the distance to which dredged material must be taken to the sea or estuary.

Information for docks.

9. If docks are intended, deep and accurate borings should be made to ascertain the nature of the strata, and the presence of springs or streams, which may interfere with excavation or building operations. The maximum size of the vessels which will enter, the depth over the dock-cill which it is desirable to attain, and also the amount of quay space required.

Depth of water and quay space.

Landing facilities.

See page 70.

10. The existing facilities for landing materials, plant or machinery, such as may be needed for the new harbour works.

11. Local information as to climate, building materials, and labour, such as has been already described, so far as they would apply to new harbour works. Special information as to the kind of stone and hydraulic lime or cement most easily procurable, either as suitable for face-work, rubble, or concrete; the existence or otherwise of ballast or clean shingle and sand for concrete; the kind of timber obtainable in the country suitable for piles and staging; with information as to the effect of marine worms, white ants, climate, or other destructive agencies upon different kinds of timber.

Climate.

Building materials and labour. *See page 70.*

Marine worms.

12. The conditions under which the new works are to be constructed, the terms of the concession, the methods intended of raising capital and applying revenue, and, generally, information on this point already referred to.

See CONCESSIONS. *Chapters II. and III.*

The construction of a Pier for landing goods or passengers is an undertaking somewhat akin to that just described, of making a harbour, and the pier often forms part of the larger enterprise. It sometimes happens, however, that a harbour is not needed or cannot be afforded, and a pier alone is constructed. Where the water shallows very gradually to the shore, and where no accommodation exists for bringing vessels alongside a quay, the inconvenience is very great, for ships have then to anchor some distance from the land; goods have to be brought ashore in lighters, and passengers landed in boats. Indeed, in some situations, as in an open roadstead, where there is surf, even a boat cannot safely be beached, and everything has to be carried ashore on men's backs. The construction of landing-piers has been facilitated by the various modern improvements in subaqueous foundations. Those specially applicable are screw-piles and cylinder supports, which are more fully described in another chapter. Screw-piles will penetrate almost every kind of stratum except rock, and when properly inserted and braced are very stable; they do not occupy much space in proportion to their strength, and their rounded surfaces offer but slight resistance to the waves. Accumulated experience in regard to marine structures has taught engineers that it is easier to avoid the force of the waves than to resist them. Except, therefore, in those cases where a breakwater is required, a landing pier is best made of open framework. Everything hollow or angular in the structure which affords a hold to the waves should be avoided as far as possible, for the mere difference between an angle iron and a round bar is in this respect very great. Groups of piles or columns,

Landing-piers.

Modern facilities for pier-construction.

Screw-piles and cylinders. *See page 116.*

Resistance to the waves to be avoided.

if properly braced together, have enormous strength to support a load, and at the same time present but little surface to the waves; and if suitably strutted and protected by fender-piles, such structures will resist also the rolling of vessels due to any but the roughest weather. All horizontal landings or staircases which, as in tidal structures, will be reached by the sea, should have openings to let the waves pass through, and the deck or platform of the jetty must be so high as never to be beaten by waves from below, or it will be liable to destruction.

Landings and staircases.

Pier-heads.

The pier-head is generally widened out, and, because more exposed, the supports are closer and more strongly braced than in the other part of the structure. In situations exposed to heavy winds or rough seas, the pier-head should be so designed that vessels can be moored in a position to leeward of the weather, whatever be the direction of the wind or tide.

As in the great majority of cases, the spans of a landing-pier are of moderate size and the loads not excessive, the individual supports are not required to be of great strength; so that columns and screw-piles of small diameter are used more frequently than in bridges. For piers, however, at which vessels are loaded and discharged; on which strong cranes have to be fixed, or railway waggons and locomotives carried; and especially when it is also desirable to have the supports few and far between, large cylinders, columns, or groups of piles are used for the foundations in the same way as is necessary for bridges. But while the ironwork of a pier resembles very much in kind and cost that of a bridge, the erection on the site is often more troublesome and expensive. The staging, rafts, or boats, which can be used without difficulty in the construction of river foundations, are in the sea often exposed to violence from the winds and waves, and during stormy weather to collisions. Special precautions become necessary for the protection of the structure during progress, and, despite these, the work is often altogether stopped in stormy seasons.

Piers and bridges compared.

Risks during erection.

Where a pier is constructed for the purely utilitarian purposes of landing and embarking passengers and goods, the undertaking is—so far as the investment of capital is concerned—in the same category as harbours, and the capital can be raised and a revenue obtained in the same way. There is, however, the important difference that a landing-pier is generally a much smaller undertaking than a harbour, and is therefore more within the means of local capitalists or of private joint-stock companies.

Pier Companies.

Breakwaters.

Where it is required that a pier shall act as a mole, or sea-wall or breakwater, a much stronger structure is required, and if an iron framework is still preferred, heavy stone or concrete work should be placed behind and between the ironwork, to which, if necessary, a smooth surface of iron plates can be attached to take the first shock of the waves. But generally, where a solid pier is wanted, it is built entirely of masonry or concrete blocks, though even in this case screw and other piles are very useful as an advance work or staging, from which the more permanent structure can be built. The unwillingness of English manufacturers to erect bridges abroad applies equally to landing-piers.

See pages 47, 48, 115.

Promenade piers.

During the thirty years ending 1877 a great number of promenade piers have been constructed on the English coasts, and they have in the majority of cases proved highly remunerative, although, partly by the desire for cheapness, and partly through want of skill in their design, many of such piers are not sufficiently strong to withstand the heavy storms which may periodically be expected. At a watering-place, where the visitors have much leisure time, a pier is sure to be welcomed, and, if well situated, generally proves the favourite place for rendezvous and promenade. A pier, once properly constructed, does not cost much for maintenance, and even a small revenue will go far in paying interest on capital.

Information necessary.

To enable an engineer to make a suitable design for a landing-pier, and a contractor to estimate the cost, it is absolutely necessary that sufficient information of the kind enumerated in the following list be furnished. The expense incurred in obtaining these preliminary particulars will be amply repaid, for unless based on actual facts, any so-called estimate of cost is utterly fallacious.

Particulars classified.

Plan of site and approaches.

1. A plan of the site, showing the coast-line, the position proposed for the jetty, its length and width, and the land approaches.

Section showing levels.

2. A section of the shore and sea-bed along the line of the proposed jetty. This section should show the levels of the road, quay, or other approaches, the slope of the sea-bed, and the soundings or tide levels of the water at all seasons.

Sea-bed strata described.

3. The sea-bed must be described (trial borings being made, if necessary), the section thus indicating the clay, sand, mud, shingle, chalk, rock, or other material of which the sea-bed is composed. It is obvious that only by a correct knowledge of the strata, from the surface down to a firm foundation, can the engineer decide the

kind, shape, and number of the screw-piles or other supports, and a contractor estimate the cost of fixing them.

The intended purpose of the pier.

4. The purpose for which the jetty is intended. If vessels are to lie alongside, their tonnage and draught should be stated; and it must be known also whether the vessels will be so exposed to the wind or the waves as to cause them to roll against the jetty.

Currents and winds.

5. The direction of the currents and the prevailing winds should be stated, as information on these points may determine the positions for vessels to lie alongside. The liability, if any, to storms; their force and effect; and the seasons at which they generally occur. If passengers are to land and embark at the jetty, information should be furnished as to the kind of vessels or boats which will come alongside, or such particulars as will indicate what staircases and landings will be required at different levels.

Landings and staircases.

Cranes for landing merchandise.

See CRANES *in Part II.*

6. If goods are to be landed, cranes have generally to be provided; and it is necessary to know where these are to be placed, and the maximum weight they will be required to lift. If fixed cranes are used, the jetty can be made specially strong at these points; while, if the cranes are to be movable, the platform must be designed accordingly.

The loads to be imposed.

See LOADS ON BRIDGES.

7. If goods are to lie on the jetty, a maximum weight per square foot of surface must be stated, for which provision must be made in deciding on the strength of the structure. The carts or other vehicles which may come on to the jetty should be described, and their weight when loaded stated. If a railway is intended, the number of lines, width of gauge, and weight of locomotives should be stated.

Sheds and beacons.

See IRON HOUSES *and* LIGHT-HOUSES *in Part II.*

8. If sheds or buildings, beacon or lighthouse, are required on the jetty, their size and purpose should be described.

Landing facilities, building materials and labour.

See page 70.

9. Information of the kind already described should be furnished concerning the facilities for landing materials, of dues or taxes, the cost of material and labour. Particulars of the timber obtainable in the country—its suitability for piles, staging, and decking, and its cost—are especially necessary.

Terms of concession.

See Chapters II. and III.

10. If assistance in furnishing capital is invited, the terms of the concession, and the data on which revenue or profit has been calculated, should be very fully stated.

[*See also* CONCESSIONS: BRIDGES: RECLAMATION; *and in* PART II. HYDRAULIC CRANES: DREDGERS: DIVING APPARATUS: PILE-DRIVERS: ROCK-DRILLS: PORTLAND CEMENT: LIGHT-HOUSES: IRON HOUSES.]

CHAPTER VII.

BRIDGES.

Highway bridges are in almost all countries constructed by the public authorities as being works of primary importance. But in many cases, and especially in new or poor countries, the demand for new bridges exceeds what the public or local revenues can afford; and the traffic has to cross unbridged rivers by ferries or fords. Therefore, while it would be preferable to have none but free bridges, and to this end to erect them all at the public cost, the accommodation can only be obtained by appealing to private capitalists, and granting them permission to construct toll-bridges. As the population increases or new districts are opened out, the necessity for more bridges is continually arising; the inconvenience being felt most seriously in those districts—of which America and several of the English colonies afford numerous examples—where the rivers are subject to floods which make them at times impassable by ford or ferry.

Bridges constructed as public works.

Toll-bridges.

Want of bridges in new countries.

Wherever the risks and expenses of construction are great, and the chances of a remunerative return doubtful, the granting of privileges to the promoters is justifiable and expedient in the interests of the community. For not only may the construction of a much-needed bridge be thus assured, but the bridge proprietors will be content with a less revenue, and therefore a more moderate tariff of tolls, than if they were to be exposed to the risks of competition in the event of their venture proving successful. Moreover, in granting privileges, the authorities may reasonably demand an efficient service in return. Bridges are frequently unfitted for heavy loads, and the

Privileges granted.

Moderate tolls prescribed.

Efficient service demanded.

proprietors, desiring a bridge sufficient only for ordinary traffic, might be unwilling to incur extra expense in providing for exceptionally heavy loads, which will add but slightly to their revenue. But it is of great importance that the passage of machinery, or other heavy merchandise, should not be impeded, and the load-carrying capacity of a proposed new bridge should be clearly specified to accord with the probable demand upon it. A concession for a bridge generally has, wholly or partially, the character of a monopoly, and it is seldom that capitalists will be found willing to invest their money in such a venture except with this condition. Occasionally, however—as in cities—notwithstanding the contiguity of other and even free bridges, the new structure may be of such convenience as to obtain a remunerative traffic. Sometimes the mere possession of a favourable site gives sufficient advantage over any possible competition: the site may be favourable in the sense of its allowing a cheaper bridge to be built than elsewhere in the vicinity, or because main roads converge to it, bringing traffic that could not go so well elsewhere. But an absolute monopoly for a certain distance above and below the proposed new bridge is of course preferred by capitalists: the distance depending on the amount of traffic which the district is likely to afford. Sometimes, however, the concessionnaires stipulate only that, until their toll-bridge has been purchased from them on terms which may be agreed, no public or free bridge shall be erected within the prescribed limits; and, the first bridge having possession of the approaches and perhaps other advantages, the risk of future competition is considered sufficiently remote. Additional value is given to a concession when it is accompanied by facilities or immunities which cheapen the cost of construction or maintenance. A Government subsidy may be granted towards the cost of the bridge, or contributions towards the capital may be made by land-owners or others who are to be benefited; such contributions taking the most effective shape when the interest on them is made secondary to a preferential interest on the capital of the concessionnaires who find the larger share, or who have the risks and responsibilities of building the bridge. Even where no direct contribution is made to the cost, the raising of capital for a toll-bridge may be facilitated by a guarantee of revenue or interest from the districts which are to be benefited.

Concessions for toll-bridges.
Monopoly.
See also page 27.

Pre-emption.
See also page 37.

Facilities and immunities.
See page 25.

Guarantees.
See pages 28—33.

Tariff of tolls.
See page 34.

Whatever the general conditions of the concession for a bridge, the tariff of tolls is one of the most important points to be arranged. The cost of the bridge having been ascertained with sufficient accuracy, it is not difficult to make an approximate estimate of revenue, and it is almost always safe to reckon on a certain growth of traffic. If a bridge is properly constructed, there is generally more certainty of a net revenue than from such undertakings as railways, because while the maintenance and working of a railway absorb 50 per cent. and upwards of the gross revenue, a bridge ought to be maintained and managed for from 10 to 20 per cent. As the traffic increases, this difference tells still more in favour of a bridge; and as new roads naturally are directed towards a bridge, and houses are built in its vicinity, a continual growth of revenue may generally be reckoned on with tolerable certainty. High tolls are not always conducive to a large revenue; and, where there is a considerable population, traffic may be much promoted by a moderate tariff. Thus, in a city with a large working population, to whom the bridge is a convenience rather than a necessity, a halfpenny toll will often produce more revenue than a penny toll; while, in a sparsely populated district, a toll even as high as sixpence for foot passengers may be justifiable and necessary to produce a fair interest on the cost of the bridge. In remote districts where the cost of materials or labour may be great, and yet where a bridge is urgently wanted, speculative bridge-builders will naturally demand a remunerative return for the capital they have expended.

Revenue.

Working expenses.

Low tariff may promote revenue.

High tariff sometimes necessary.

Besides the conditions referred to of load-carrying capacity and a moderate tariff of tolls, concessions for bridges are usually burdened with other conditions, such as—that the bridge shall be of a certain width; that the roadway shall be of a certain material, and shall (with sometimes also the approaches) be maintained in good order by the concessionnaires, and well lighted; that Government traffic or troops shall be taken free or at reduced tolls; and that the community shall have the power of buying the bridge after a certain period, on terms agreed upon beforehand; and it is of course important that these conditions shall be equitable, and not weigh unduly upon the enterprise. Where a bridge takes the place of a previously existing ferry, it is sometimes also stipulated that in the event of the bridge being destroyed or becoming unsafe, the concessionnaires shall re-establish and maintain the ferry at the old rate of tolls till the bridge is again rendered available.

Obligations of Concessionnaires.
See page 33.

Although it is for road traffic that the great majority of toll-bridges are constructed, railway-bridges also sometimes depend for their revenue on tolls. This is especially the case in the United States,

Toll railway-bridges.

where railways and groups of railways are often divided by the great rivers which intersect the country; the expense of building bridges often forbidding their construction in the first instance when the railways are projected: the traffic being carried across by means of a floating-bridge or ferry-boats, or by a long *détour* to the nearest bridge. The consequent inconvenience often proves so great as to induce capitalists to build a bridge as an independent enterprise. A competent engineer having been found to design the bridge, and trustworthy contractors who will build it for a certain sum, a company is formed with a capital based on this estimate of cost. The different railway companies who may each be unable or unwilling to undertake the whole cost, may be able and willing to contribute towards the capital of an independent company. Sometimes the railway companies do not embark even the smallest sum in the risks of construction, but agree only to contribute a certain amount when the bridge is completed. Again, in other cases, no contribution towards the capital is made even after completion, but the entire cost is left to the bridge company; each railway engaging to send a certain minimum amount of traffic over the bridge at pre-arranged rates of toll.

Traffic guaranteed. *See page 28*

Having a revenue thus secured, investors are encouraged to embark money in the enterprise. Sometimes the railway companies go still further, and guarantee interest at a rate equal to or greater than their own on some or all of the share-capital of the bridge: the revenue or interest thus guaranteed may be sufficient to pay a dividend on a certain amount of preference-shares, mortgage-bonds, or debentures, which may be equal in amount to the actual expenditure in the construction of the bridge; and the promoters or the bridge company may look for a profit, beyond the mere interest thus ensured, in the possible earnings of the bridge in excess of the guarantee. These extra earnings are generally applied to payment of dividend on "deferred shares," which, though less certain of dividend than the preference-shares or mortgage-bonds, have a speculative value depending on the traffic or earnings of the undertaking. When such engagements are made by railway companies of good standing, and especially where the guaranteed interest on the bridge capital is preferential to the interest on the railway companies' own capital, the undertaking becomes a sound one for the bridge proprietors, whose risk is then confined to the construction of the bridge and its maintenance afterwards. Although cases of this sort are more usual in

Guaranteed interest. *See page 31.*

Toll-bridge companies in United States.

the United States, where many wide rivers have to be crossed, the same sort of arrangement has been found necessary in England also; the Severn Bridge at Lydney, the Severn Tunnel near Bristol, and the Tay Bridge in Scotland, affording examples of undertakings assisted in one shape or other by the contiguous railway companies who are interested.

Erection of bridges.

Manufacturers of bridges are generally called upon to erect them if the site be in their own country; and such a condition is made part of the contract. But, except in the case of very large or numerous bridges, the erection in a foreign country is seldom carried out by the manufacturers, as the undertaking is one not large enough to repay the trouble and expense such a course would involve. Although there are certain advantages in maintaining the responsibility of the manufacturer till the bridge is completed and tested by actual traffic, there is nothing so peculiar in the erection as to prevent a local engineer from undertaking it. If the bridge has been properly designed, and if the quality of the material and workmanship has been verified by inspection in the factory, and if the various pieces be properly marked, an experienced superintendent, or skilled mechanic, furnished with a drawing, will have no difficulty in erecting a bridge he has not seen till it arrives on the site; and it is generally much cheaper to employ such a superintendent than to include the erection in the manufacturers' contract. Where, however, it is considered very important that the manufacturer should erect the bridge, he will be the more ready to agree to such a proposal if those risks which are to him unknown, but with which the purchasers in a foreign country are familiar, be removed. Thus the purchasers may agree to take the bridge material and the tools from the ships' side at the port of arrival, and convey them to the site; to pay all dues and imposts; to provide necessary staging or flooring-timber free or at agreed rates; to furnish unskilled labourers; and generally to give all the advantages which their local knowledge may afford.

Manufacturers unwilling to erect abroad.

See page 48

Local purchasers may grant facilities.

Choice of bridge, how determined.

In deciding upon the kind of bridge which shall best satisfy any particular case, various circumstances have to be considered, which may, however, generally be divided into three classes, as—

1. The Exigencies of the Site:
2. The Necessities of Manufacture:
3. Considerations of Economy.

Exigencies of the site.

1. *The Exigencies of the Site.*—The length of the spans into which a bridge shall be divided depends on the cost and convenience of

numerous piers, as compared with those of long spans. The weight of an iron structure depends primarily upon the span, because the weight per lineal foot increases with the distance between the supports; a bridge of 100 ft. span weighing about three times as much as a bridge 50 ft. span, similar in all other respects.

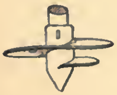
Short spans compared with long spans.

It is obvious that such a comparison depends upon the circumstances of each particular case; for, while a bridge at a low level over a wide, shallow river, with a bed affording an easy foundation, may allow numerous piers to be cheaply constructed, a deep river running between high banks, or one offering impediments to sub-aqueous work, may render intermediate piers so expensive as to make long spans preferable. The question of spans may be also affected by the necessities of navigation, or the passage of floods or ice, to which piers might form a too great obstruction.

Iron piers.

Screw-piles.

But, whatever the kind of bridge, the piers and the superstructure should be considered separately. Iron piers are composed either of piles or cylinders. Screw-piles are made either as solid columns of wrought-iron or steel, or as hollow columns of cast-iron, the piles having in either case a screw at the point, so that when turned by a capstan the piles can be inserted into the ground till a firm foundation is reached. The length of each pile, as delivered at the site of the bridge, is determined partly by the necessities of manufacture, and partly by the exigencies of transport. Solid piles are generally of some diameter between 4 in. and 9 in., and can be rolled in lengths of from 10 ft. to 20 ft., according to their diameter and weight. The separate lengths can be united by couplings of various kinds, as is done for the revolving shafts used in factories, but, by welding, the piles can be made in one length without external flanges or projections of any kind; convenience for transport, however, limiting the length to 30 ft. or 40 ft., as the case may be. Cast-iron piles are generally made in pieces of from 9 ft. to 16 ft. long, and are united by internal or external flanges, or by sockets. When iron is at an average price, solid piles properly prepared and jointed cost from £13 to £17 per ton, and cast-iron piles from £9 to £12 per ton. Iron piles are sometimes driven into place by a falling weight: in such cases they are pointed at the ends, and, if of wrought iron, are best made of a hollow, ribbed section. Iron pile piers are most frequently used for supporting spans of from 20 ft. to 70 ft., as beyond this span groups of piles would be necessary, and cylinders of larger diameter generally become preferable.



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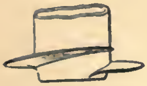

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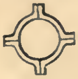
Average prices.
See FLUCTUATIONS IN PRICES *in Part II.*



6.

Pier cylinders.

Fixing of cylinder piers.

Pumping from cylinders.

See PUMPS *in Part II.*

Pneumatic method.

Divers.

See DIVING APPARATUS *in Part II.*

Pier cylinders are generally of some diameter between 3 ft. 6 in. and 16 ft., and are in most cases of cast-iron from ¾ in. to 1½ in. thick. Made in lengths of from 6 ft. to 9 ft., they are united by flanges, and are frequently (when over 5 ft. diameter) divided into segments, for convenience of transport. Although cast-iron is the most suitable material, the cylinders are, where there is very great risk of breakage, made of wrought-iron plates, about ⅜ in. or ½ in. thick, riveted together and stiffened by L irons and ring-shaped frames. In almost all cases cylinders are forced down by weight, but as it is generally necessary to clear out the soil within, either to assist the cylinders to descend or to make room for the solid pier which is to be constructed, various auxiliary methods are applied. For moderate depths, scoops or dredging buckets, can be used from the top; but in many cases it becomes necessary that workmen shall descend to dig out the soil. If the stratum be clay, the cylinder can be emptied of water by pumps, or, if the clay be not quite water-tight, kept free of water by pumps while the men are working; but if of gravel, sand, alluvial soil, or rock, pumps will seldom overcome the water. In such cases the men must work in the diving-dress, or the cylinder must be closed at the top and treated as a diving-bell, the water being forced out by air-pumps. The difficulty becomes greater as the depth (and therefore the air-pressure) increases, and special arrangements become necessary when the cylinders have to penetrate more than 70 ft. from the surface of the water. The pneumatic system of sinking cylinders is somewhat expensive, and as the apparatus and preparations bear a high proportion to the total cost of small bridges, it is seldom used except for large bridges, divers being generally preferred. Great care is necessary to ensure the cylinders reaching a firm stratum not liable to be undermined, or weakened by the scour of the water.

By using iron piles or cylinders, the water-way of a river is less obstructed than by the more bulky masonry piers; but, except for this reason, the only superiority which iron has over masonry is in the facility afforded during construction, as iron piles or cylinders can be fixed without the cofferdams usually necessary for masonry. In some cases the two systems are combined: cylinders are sunk not as permanent supports, but because, as caissons or cofferdams, they allow concrete or masonry to be built within them: the iron shell being, however, generally retained.

Brickwork cylinders for piers.

Cylinders of brickwork are occasionally used for bridge piers,

Mode of sinking brick cylinders.

Brick cylinders in India.

Concrete cylinders.

See also page 102.

where the soil is loose or sandy, and especially in countries where ironwork is expensive, and clay suitable for bricks is abundant. The cylinders are built upon the ground on an iron ring or curb, and the soil being excavated within by scoops, dredging-buckets or sand-pumps, the cylinder sinks, additional brickwork being added above until the required depth is reached. The inside is then filled with concrete. If the soil be very loose, the cylinder—to prevent it sinking too rapidly—may be suspended during the process by iron rods attached to the curb plates. This system of brick cylinders was used—principally for wells—many years before the introduction of iron cylinders, and in more recent times it has been employed very extensively for bridges in India. Concrete, as being often more conveniently obtained or applied than brickwork, has also been used for pier cylinders, this being one of the many useful applications of this comparatively new material.

Classification of bridges.

Bridges may be classed in various ways, and each kind—Girder, Arch, and Suspension—again sub-divided into classes. In regard to the superstructure, it may be said concerning all types of bridges that the importance of selecting an appropriate form increases with the length of the span. In small spans it is almost impossible to construct a bridge which shall accord exactly with the forms and strength of parts which theory might prescribe, and as there is this latitude, any one of numerous forms may be made of sufficient strength without much variation in cost. As the span increases, the choice of design is narrowed, a correct decision becomes more difficult, and an error in judgment, or departure from the exact form which may be the best for the purpose in view, tells with great effect.

Girder bridges generally the cheapest.

See page 131.

Type of bridge determined by the levels.

For spans between 30 ft. and 150 ft., iron girders form the cheapest kind of superstructure both for road or railway bridges, except in cases where natural or easily-formed abutments facilitate the construction of arched bridges, or where certain secondary reasons, presently to be described, prevail. From the present point of view, *i.e.* that which concerns the site, it will generally be found that the levels of the bridge or the approaches in their relation to the river, primarily determine the type of superstructure; and the levels may forbid the application of certain systems which require parts of the structure to be too low beneath the platform of the bridge. The different kinds of bridges which are designed to meet this question of levels are illustrated by the examples that follow on pages 133 to 144.

Transport and erection may be also included under this head. If there be long inland carriage over bad roads, the parts must be made of moderate size and weight; and certain systems of construction give more facilities than others in this respect. The manner in which girders shall be divided depends on their design; connections and joint-covers having to be carefully considered, not only in regard to their ultimate purpose, but to their temporary division. It is often expedient to pay a higher rate for carriage if subdivision may thereby be avoided or reduced; cross-girders, for instance, may almost always be sent entire, and the principal parts of main girders also, when the length of such parts does not exceed 30 ft. (or in rare cases even 40 ft.), and the weight five tons.

Transport of materials.

Division of pieces for carriage.

See EXPORT *in Part II.*

Size and weight of pieces.

Sometimes skilled labour cannot be procured, and designs must be adopted which do not require skilled mechanics at the site. In other cases, the want of timber, or the nature of the river, renders the use of staging expensive or impossible, and bridges must be designed which can be erected from the shore or in some other way without staging.

Erection without staging.

2. *The Necessities of Manufacture.*—It is always expedient to utilise, as far as possible, the materials and modes of construction which are most easily attainable; and in regard to bridges, these conditions are not everywhere the same. There is an immense variety of shapes and sizes of rolled iron made in England for structural purposes, but some are much more expensive than others; and it is not always easy to obtain quickly small quantities of a particular kind. The design which requires the least weight of material may, for these reasons be more expensive than a heavier and simpler design. If, for instance, in a small span the engineer were to vary the dimensions and thicknesses of the individual parts to accord exactly with the strains to be endured by them, such a variety of sizes of rolled iron might become necessary as would involve unremunerative trouble, expense, and delay, in the manufacture. Again, theory may in some cases prescribe as the most suitable disposition of material, curved or irregularly-shaped girders, but it may be taken as a general rule that the simpler the design the better. A variety of shapes and dimensions in the different parts — unless cheapened by the quantity of each and consequent economy which numerous similar parts allow—would prove more expensive than a parallel girder of simple form. Of course there may be secondary reasons which

Necessities of manufacture.

Variety of rolled iron.

See IRON *and* STEEL *in Part II.*

Simple designs generally the best.

justify a reduction in weight, even at an increased cost in the manufacture; such reasons, for instance, as high rates of freight, or of import duty charged according to the weight; or a desire for what may be considered the more pleasing appearance of the curved or irregular girder.

English and American bridges compared.

Pin-connected *versus* riveted bridges.

Pin bridges easily put together.

Want of rigidity during erection.

Certain types of bridges demand particular kinds of workmanship; as may be most readily illustrated by the radical difference between the bridges usually made in England and in the United States. In England, riveted connections for wrought-iron bridges are generally adopted by engineers, in preference to the system by which the connection is made at each intersecting point by a single pin. There are certain advantages in the latter system which are admitted by all engineers,—such as, that the strains on a single pin may be easily calculated and controlled, while the rivets of a group are always strained to a varying extent, and that therefore by a single pin the direction of strain may be made to follow the central or axial line of each part so connected with more certainty than is possible with a group of rivets; and a saving in weight may be so obtained. Pin connections also in some cases afford facilities for erection, as girders so constructed can be quickly put together, and if skilled workmen cannot be obtained at the site, there is not the risk which attends imperfectly executed riveting. On the other hand, a riveted girder can be handled (as a whole) with greater facility, and can often be launched or dragged over from the shore without the necessity for staging, in cases where a pin-connected girder having the tension member composed of links would collapse while temporarily exposed to such abnormal strains.

American trussed bridges.

See also pages 136 & 144.

Machine-made links.

Riveted connections are, by English engineers, generally considered as more permanently homogeneous and enduring both against rust, and against wear and tear, than is the case with the pin connection. But riveting, to be effective, must be well executed; the holes in the different pieces must exactly coincide and the rivets completely fill them; and in these respects the workmanship in the principal English factories has been brought to a high standard of perfection. In the United States the various forms of trussed bridges, which have been adopted both for highway and railway traffic, are designed with pin connections, and the processes of manufacture are directed towards the carrying out of this system. Machine-made links, with heads and eyes formed in dies or by machinery, are made in large numbers precisely alike; and the scope which a new country allows in regard to the choice of design, and the custom of the trade by which manufacturers sell continually their own fixed types of bridges, have led them to adopt these repetition methods. Riveting is not (1877) performed in the United States with the same accuracy as in England, and so long as this is the case, the pin system, if properly carried out, is the safer one there. In England, although large numbers of pin bridges have been made—including many most important structures—the system by which the constantly varying designs of numerous professional engineers are presented to the manufacturer for execution, forbids the adoption in the factory of models, dies, and machinery, which only with a certainty of repetition can be justified. As a rule, therefore, riveted girders are the cheapest as well as best if made in England, except in cases where a considerable number of similar spans allows machine processes to be introduced with economy, or where for necessities of erection, certain facilities which the pin system allows have a special value. But it is essential that the connections and groups of rivets be skilfully designed, and that the iron and the workmanship be good—conditions not always obtained, if price be the only standard of comparison. In the United States it would generally be a mistake to purchase a riveted bridge, and the purchaser must select from the limited class of efficient manufacturers one of the particular types of pin-bridges which each has adopted as his own.

Repetition methods.

Fixed types impossible in England.

Riveting must be well executed.

3. *Considerations of Economy.*—In designing a bridge the engineer has not only to satisfy the exigencies of the site and the necessities of manufacture, but has to conform to certain standards of quality and fitness which may be varied within very considerable limits. That is to say, bridges, like other engineering works, may be made either in a very strong and permanent manner, with the maximum accommodation, or in a manner less stable or convenient. Much, of course, depends upon the amount of money available, and in some cases necessity may compel the erection of a cheap structure affording limited accommodation, strength, or term of endurance, and involving additions, repairs, or renewals, at a comparatively early date. The points which are thus left open, and upon which the engineer can only advise those who employ him, are:—

Considerations of economy.

Cheap and imperfect structures.

(*a*) The Material of which the bridge is to be made—wood, stone, iron, or steel.

(*b*) The Width of Roadway for convenience of traffic.

Conditions of cheapness elucidated.

(*c*) The kind of Roadway Material, which, according as it is made light as of timber, or heavy as of macadam or granite paving, will determine greatly the necessary strength, and therefore the cost, of the structure which is to support it.

(*d*) The amount of Moving Load which is to be provided for, and whether and how far exceptional loads or possible increased loads in the future are to be considered.

(*e*) The Margin of Safety required; that is to say, whether the bridge when sustaining its maximum loads shall be strained to one-fifth, one-fourth, or one-third of its ultimate theoretical failing point.

(*f*) The degree of Ornamentation which is to be included in the design.

The above points may be further elucidated as follows:—

Bridge materials compared.

(*a*) *The Material of which the bridge is to be made.*—In countries where timber is plentiful and the climate favourable, *Timber* (either alone or in combination with iron tension rods) may be employed with advantage where economy is desired. Thus in the United States, Canada, Russia, and Scandinavia, timber may be obtained cheaply; workmen are skilled in using it; and the climate is generally favourable. But the term of endurance in timber bridges is at best much less than with iron or stone; they occupy much space; they are liable to destruction by fire; and the limit of span is not great. Therefore, where the requisite funds are available, iron is preferred even in timber-growing countries, and especially for railway bridges.

Timber bridges.

Stone bridges.

Stone is well suited for arched bridges, and so applied is both long-enduring and pleasing in appearance; but skill, not always available, is needed for constructing stone-bridges, and for designing the temporary timber centerings on which the arches are built; strong abutments are needed to receive the lateral pressure of the arch; the high curve often renders the approaches inconveniently steep, and beyond a span of 100 ft. stone bridges are difficult of execution.

Brick bridges.

Where foundations are easily constructed, and the height is small, and where, therefore, numerous small spans compare favourably in cost with long spans, *Brick* arches are often preferred in countries where clay for bricks is abundant. In India, for example, long viaducts have in this way been constructed more cheaply than would have been possible with iron girders.

Iron bridges.

It is needless to enumerate the various advantages afforded by *Iron* in the construction of bridges; but in the case of foreign countries where engineering skill and appliances are wanting, the fact that bridges can be designed and manufactured in a distant country and conveyed in pieces to the site of erection, is alone a sufficient justification for their use. The application of iron to bridge structures allows greater scope to the engineer than was possible when stone and timber were the only available materials; and as the great majority of modern bridges, or at least their superstructures, are made of iron, it may be said that an entirely new field has been opened out to the bridge engineer. For some time after iron was used for the superstructure of bridges, the difficulty of erection prevented its application for bridge piers; but the invention of screw-piles and the numerous systems of cylinder piers have given to the engineer a choice of methods, wide enough to meet almost every case.

Steel bridges.

The many modern inventions in connection with *Steel* have rendered it more available than formerly as a material for bridges; but there are various considerations which limit its use. Up to the year 1870, if wrought-iron and steel were compared in regard to those qualities which render them suitable for structures, and if also their respective costs were compared, it would be found that the qualities and the money-values were in very different ratios. Thus when iron having an elastic limit of about 10 tons per square inch was selling at £10 per ton, steel of similar shape, but with an elastic limit of 16 tons, would cost about £20 per ton; iron girders costing about £17 per ton, and steel girders about £30 per ton. From this one point of view, steel would appear to present no advantages; but since 1870 the prices of steel have continued to approach those of iron, and in 1877, instead of a difference of 100 per cent., steel was only 60 per cent. dearer than iron. But steel, besides being stronger than iron, has generally a harder surface, and so is more capable of enduring wear and tear. Steel, moreover, is—strength for strength—much lighter than iron; and it is this quality which principally renders it occasionally useful for bridges. It is not always practicable, especially in short spans, to reduce the thickness of some of the parts by using steel; and for secondary reasons, such as liability to vibrations and deterioration from rust, engineers would hesitate to use steel thinner than ¼ in. Thus a bridge of 80 ft. span, which if of iron might weigh 25 tons, would probably not weigh less than 20 tons if made of steel; and there is no particular advantage in having a bridge 80 ft. span made of 20 tons of steel, instead of an iron bridge of similar span and strength, weighing 25 tons, even if they

Steel compared with wrought-iron.

Strength and cost.

Lightness of steel.

Steel not advantageous for small spans.

Steel becoming cheaper.

both cost the same. Indeed, for small spans, where the weight of the structure is not great in proportion to the moving load, the steel bridge would be less steady and stable than the heavier iron bridge.

Useful application of steel.

Long-span bridges.

Saving in cost of carriage.

Steel, even under some of the conditions above described, compares favourably with iron in the following cases: When great tensile strength is wanted in small compass, as in tension-links or wire-ropes in large-span bridges; or where, because the weight of the structure bears a considerable proportion to the total load to be carried, a reduction in this dead weight becomes important. Steel has been successfully applied in this way for some of the most famous modern long-span bridges; and the limit of span in a bridge is obviously much increased by the use of steel. But spans longer than 200 ft. are rare; and it is only when this span is exceeded that the use of steel has, except for special or local reasons, offered any advantage. The lightness allowed by the use of steel reduces the cost of transport, and it is in such cases as those entailing long and expensive inland carriage that steel could be used with economy.

Other causes which limit the use of steel.

See **IRON** *and* **STEEL** *in Part II.*

Uncertainty as to quality.

Want of official sanction.

Board of Trade regulations.

But, while the price of steel as compared with that of iron was such as to confine its use to the cases above described, its application was also limited by other circumstances, which, as most of them have been radically altered in a few years, have, under such altered conditions, to be weighed differently. The art of manufacturing steel has been in a transition state; great uncertainty has prevailed among engineers as to its exact quality; manufacturers did not, even with the powers they possessed, always produce the best kind in regard to strength and elasticity for the purpose in view; and experiments revealed that out of a given number of pieces, some would be found defective or deficient. These uncertainties restrained engineers from using steel even in cases where its employment would have been advantageous. Moreover, even when these difficulties and uncertainties were removed (as most of them effectually have been), and the price brought very much lower in proportion to that of iron, the extended application of steel has been still retarded by the want of official sanction. Thus the Board of Trade regulations for railways in Great Britain prescribe that the parts of an iron bridge must be of such dimensions as would involve, when the greatest load is imposed, not more than 5 tons strain per square inch on any part. No provision has up to the year 1877 been made for any higher strain for steel, and without such official sanction to higher strains, the extended use of steel for railway bridges in England has been prevented. And as the English practice determines greatly the kinds of bridge materials which are made, bridges designed and made in England, even for countries where the Board of Trade regulations do not apply, have followed mainly the system usual in England.

Alteration of rules in favour of steel.

Extended use of steel probable.

The improvements in steel have, however, become so manifest, that the Board of Trade, after numerous appeals by steel-makers and engineers, and after careful investigation, has inaugurated new rules, which allow in railway bridges 6½ tons per square inch to be the limit of strain for steel, instead of the previous 5 tons which applied to iron and steel alike. This concession of 30 per cent., though it does not perhaps allow the application of steel to the extent which its qualities justify, is an acknowledgment of the principle which will doubtless be amplified hereafter. The comparatively small number of forms—plates, L, T, and other bars—suitable for structures in which steel has been manufactured, as compared with the larger number of forms in iron, limits its application at first even after the new rules are in force; but the appliances for steel-making are so complete, and the processes are so cheapened, that a demand for suitable forms of rolled steel will almost certainly result in an extended trade, and at prices so reduced as to allow steel bridges to be made more cheaply than iron bridges. Steel of high quality can in many cases be used with advantage for strains as high as 10 tons per square inch, but such an application of steel should be strictly limited to those simple forms—of which tension-links are an example—where every piece can be tested.

Risks in the heating of steel.

The smithing of steel, and the risk of spoiling steel rivets in the heating, are two of the minor difficulties which have to be overcome in the proper adoption of steel as a material for bridges.

Width of roadway.
See Examples, pages 133—144.

Width of vehicles.

London Bridge.

(*b*) *The Width of Roadway.*—The width of a railway-bridge is determined by the gauge and by the railway having a single or double line; but a highway bridge allows considerable latitude within which cheapness may be obtained by narrowing the platform. If vehicles pass rarely, a bridge wide enough for one only may be sufficient, but in the case of long spans, narrow bridges are objectionable, because of their deficiency in lateral stability. Assuming that the extreme width of a vehicle is, as in England, about 8 feet, then the width of the roadway, in addition to the footpath, should be made to accommodate a certain number of vehicles; 9 ft. within the curb is considered sufficient for one; 18 ft. to 20 ft. for two; while on London Bridge, which may be taken as an example of a city bridge carefully designed, 35 ft. is the width provided for four lines of vehicles. By marshalling the traffic into two lines in each direction, one line being formed of quick and the other of slow vehicles, and by forbidding halting on the bridge, a much larger traffic may be accommodated than where such regulations are wanting. A width sufficient for three or five vehicles is sometimes adopted, as the space between the lines of traffic enables quickly-moving vehicles to pass by a slow vehicle which is blocking the way. Southwark Bridge and Waterloo Bridge on the Thames, are so constructed, each having a roadway 28 ft. wide, and two footpaths of 7 ft. Westminster Bridge has a total width of 82 ft., of which 54 ft. are given to the roadway, and 14 ft. to each of the footpaths. In country districts, bridges are sometimes made without separate side-walks for foot-passengers, but in such cases the roadway must be wide enough, or recesses must be provided, to allow for the safety of foot-passengers during the passage of vehicles.

Marshalling of traffic.

Width of Thames bridges.

(*c*) *The kind of Roadway Material.*—The selection of roadway material is governed by the kinds which are obtainable in the neighbourhood of the bridge; by the nature of the traffic; by the climate; by the degree of permanency desired; and, finally, by the cost, both in regard to the material itself, and to the weight and consequent strength required in the bridge. Timber is the lightest material, but if used as part of the structure will not last long, and is subject to destruction by fire. For foot-bridges, however, timber is frequently used, as the wear upon it is not great, and it can easily be renewed. In climates like that of Russia and Canada, timber boards are often used for highway bridges, an upper layer of wearing planks, which can be renewed, being generally placed upon a complete timber platform. Timber blocks may be used on iron highway bridges, and such a roadway weighs from 40 lbs. to 60 lbs. per square foot of surface, including 8 lbs. for gravel, bitumenised ashes, or asphalte, on which to bed the blocks. Macadamised roadways are commonly used on highway bridges, and from eight inches to fourteen inches of macadam or macadam on concrete is generally adopted, the exact thickness depending on the nature and frequency of the traffic. For every inch in thickness of concrete or macadam, a weight of about 10 lbs. per square foot of surface is imposed. In cities where constant and very heavy traffic must be provided for, granite blocks embedded on concrete are frequently used, and for this kind of roadway a weight of from 200 lbs. to 300 lbs. per square foot should be allowed.

Roadway material.

Timber platforms.

Wood blocks.

Macadam.

Granite blocks.

Macadam road material is sometimes placed on a timber platform; but for any of the materials enumerated above, except wooden planks and blocks, a complete platform of iron plates should be provided. Generally, rolled wrought-iron plates either flat, curved, buckled, or corrugated, of from ¼ in. to ⅜ in. thick, are used, and as such plates, including fastenings and connections, add from 12 lbs. to 20 lbs. per square foot to the weight of the bridge, the cost of the structure is thereby greatly enhanced. Very great care, both in design and workmanship, is necessary to keep the platform of a wrought-iron bridge water-tight, especially under railway traffic. Cast-iron is admirably adapted for the platforms of highway bridges which have to sustain very heavy loads: such plates are made in various forms—flat, ribbed, buckled, or corrugated; they can by caulking be made permanently water-tight, and they are more lasting against rust than wrought-iron plates. In the case of a strong cast-iron arched bridge to carry heavy city traffic, with a roadway either of granite, macadam, asphalte, or wood blocks, a substratum of concrete on cast-iron plates is the best that can be adopted.

Platform of iron plates.

Iron platforms seldom water-tight.

Cast-iron plates. *See Example* L.

In iron railway bridges the cheapest plan is to have no deck or roadway material, but to lay the rails upon longitudinal or cross-sleepers placed directly upon the bridge framework. Such a plan is frequently adopted in the United States, but as sometimes the trains have left the rails on such bridges, and the sleepers, unable to resist the shock, have given way and allowed the train to fall through, the system is not allowed in countries where laws or official regulations have more regard for the public safety. In the best railway bridges a platform of iron plates is constructed, upon which ballast can be laid, so that the ordinary system of permanent-way is unaltered: the ballast acts as a cushion on which the trains run smoothly and with the minimum of noise; and there is no danger from fire. In other cases, where the rails are laid on longitudinal or cross-sleepers without ballast, a complete deck of strong planking is provided, resting on cross-girders sufficiently near together to sustain a train which has left the rails; and such a deck can be covered with sand, ashes, or sheet-iron to render it uninflammable. Guard timbers may be conveniently placed to keep a train from leaving the track. In designing a bridge to sustain a certain dead weight of road-material, a margin should always be allowed for additional weight which may at some future date be inadvertently put on the bridge.

Railway bridges without deck. *See Example* B.

Ballast on bridges. *See Example* R.

Wood deck for railway bridges.

(*d*) *The amount of Moving Load to be provided for.*—The weight of

Moving loads.

Weight of a crowd. a crowd of persons has been estimated variously by different engineers at from 60 lbs. to 120 lbs per square foot. A dead weight of 80 lbs. may generally be assumed as sufficient, for with any greater density movement becomes almost impossible.

Weight of vehicles. With regard to the weight of vehicles on a bridge, it is seldom that an average load of more than 45 lbs. per square foot, or 360 lbs. per lineal foot of each line of traffic, is put upon the whole surface of a bridge, except in the case of small spans (say, under 50 ft.); and even London Bridge when most crowded would not have more. But the effect which loaded vehicles have upon the structure depends greatly on the length and width of the space covered by the vehicles, their overhanging loads, and the horses, and on the length and width of the wheel base. **Concentrated loads.** Very heavy loads are frequently concentrated upon four wheels, and with special vehicles even upon two wheels; **Traction engines.** *See* PORTABLE ENGINES *in Part II.* while the modern use of heavy traction-engines and steam-rollers renders the likelihood of extreme loads greater than formerly. Provision must therefore be made in the strength and arrangement of the cross-girders and other local parts which may have to sustain concentrated loads. As such heavy loads pass rarely, there need not, however, be so great a margin of safety as for the general total load. **Prescribed loads.** The load which in the modern practice of bridge-building is generally provided for, varies from 60 lbs. to 100 lbs. per square foot of the entire surface: the lower weight being considered sufficient for bridges in colonies and new countries where the traffic is small, and the heavier weight for city traffic. **Effect of heavy loads on small spans.** In the case, however, of spans under 40 ft., it will be found that the necessity for providing for a concentrated local load will bring up the average for the entire surface much higher than for the longer spans, while for spans longer than 100 ft. a less load may be assumed, although for these longer spans, in cases where heavy road material is used, it is of small consequence whether the moving load be a little more or less, as such a circumstance has but slight effect on the total strains on the bridge. The following may be taken as safe limits, the exact weights depending on the locality and likelihood of heavy traffic :—

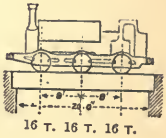
Safe limits of loading.

Bridges under 40 ft. span ...	100 lbs. to 150 lbs.	per square foot.
Bridges 40 ft. to 100 ft. span ...	80 lbs. to 100 lbs.	,,
Bridges more than 100 ft. span..	70 lbs. to 80 lbs.	,,

Moving loads on railway-bridges. In the case of railway bridges, the heaviest weight is that of locomotives placed end to end, and for the standard-gauge lines in

England 1½ tons per lineal foot for a single line, and 3 tons per lineal foot for a double line, are prescribed by authority. But for spans shorter than 40 ft. the concentrated load of a heavy engine with a short wheel-base will tell with greater effect, and the bridge should be made stronger accordingly. For example, with a heavy tank-engine weighing when equipped 48 tons on a wheel-base of 16 ft. (this being an example of the heaviest concentrated weight of an English locomotive), a load equal to a distributed weight of 2¼ tons per lineal foot would be imposed on a bridge of 20 ft. span, although since the extreme length outside the buffers would be 30 ft., no more than 1½ tons per lineal foot could be imposed on a bridge of 100 ft. span, if a train of such engines were placed upon it. As these facts have not always been properly appreciated, there are railways in which the short-span bridges are too weak and the long-span bridges unnecessarily strong. In the official regulations of some foreign countries, it is considered unnecessary in the case of long-span bridges to provide for a load of locomotives all over the bridge, and beyond 100 ft. span the 1½ tons per lineal foot for each line of way is reduced. The following are safe limits for standard-gauge railways :—

Heavy engines on short wheel-base.



7.

Prescribed loads for railway bridges.

For spans up to	20 ft.	2¼ tons	per lineal	foot	(for each line).
,, 20 ft. to	50 ft.	2 ,,	,,	,,	,,
,, 50 ft. to	80 ft.	1¾ ,,	,,	,,	,,
,, 80 ft. to	120 ft.	1½ ,,	,,	,,	,,
,, above	120 ft.	1¼ ,,	,,	,,	,,

Safe limits of loading.

In regard to the loading of railway bridges, it must be borne in mind that locomotives have been made much heavier than formerly; and as the use of heavy steel rails facilitates the employment of heavy engines, a still further increase of weight must be looked upon as possible by the bridge designer. On the other hand, modern locomotives are designed with more regard than formerly to an equal distribution of the load on the various wheels, and this of course reduces the local pressure upon the individual cross-girders of a bridge.

Locomotives heavier than formerly.

See LOCOMOTIVES *in Part II.*

(*e*) *The Margin of Safety required.*—There are various ways of estimating or expressing the margin of strength which is given to a bridge. Generally the dead weight and moving load are added together, and the strain upon the iron due to the total load thus obtained is compared with the supposed breaking strain of the iron. But by some engineers the dead and moving loads are considered separately,

Margin of safety.

Dead and moving loads considered separately.

Deterioration by rust.

Painting of wrought-iron.

the former being treated as constant, and the latter (as the one to which wear and tear, vibration, and possible accidents will be due) being taken as the important factor. From this point of view the degree of safety is stated according to the number of times the moving load may be multiplied before the bridge will break. Regard should also be given in the calculation to another important consideration, which is only slightly due to the moving load, namely, the deterioration of the bridge by rust,—a point which is unfortunately often neglected. Although there has not yet been sufficient experience of modern iron bridges to allow a proper estimate of their term of endurance, it is probable, from the experience already accumulated, that bridges of the strength given by the best engineers will last, even under railway traffic, for a very long time, if they are so designed as to allow access to all parts for painting, and if the painting is properly attended to. England, because of its climate, affords conspicuous examples of the effect of rust, especially in towns where there is a vitiated atmosphere, and the painting is too often considered a matter of small importance. The painting of wrought-iron at the time of manufacture, if done only in the ordinary way, is of far less consequence than the proper painting after the first coatings of paint have decayed: for unless the black scale, or peroxide (formed on the iron by its contact with the air during rolling), is removed, as—in England—is customary only as a prelude to galvanising, neither oiling nor painting will permanently prevent the scale from coming off. Cast-iron (if the outer skin be preserved) is much less vulnerable.

Various degrees of safety.

The margin of safety given by engineers varies from three to five times the total load. As the strength of a bridge must almost always diminish by rust and by wear and tear, a margin of four times is the least that should be given, particularly in railway bridges where the greatest loads occur more frequently than in highway bridges, and with a more percussive effect.

Excessive loads.

Limit of elasticity.

See IRON *and* STEEL *in Part II.*

Although the method of stating the margin of safety by a comparison of the working load with a breaking load is usual, and has therefore been followed here, it should be observed that a bridge will be irreparably damaged with a load much less than that which would break it. The limit of elasticity in iron, or the point at which it ceases to recover its shape after a strain is removed, is generally about one half of the ultimate or breaking limit. Thus in a bridge made of iron equal to a breaking strain of 20 tons per square inch, 9 or 10 tons per square inch would probably be its limit of elasticity, and if once loaded beyond this point it would never recover from the stretching or deflection it had undergone. And as the joints and other parts would have been permanently elongated, they would be more liable than before to become rusty or loose ; and the term of endurance of the bridge would be reduced, even if such a heavy load were never again applied.

Evil effect of over-straining.

(*f*) *The degree of Ornamentation.*—Iron bridges, especially girder bridges, often offend the eye by their shape or obtrusiveness, and the engineer is blamed for a want of taste in his design. Too often, however, the exigencies of the site render it impossible to give a graceful appearance in a structure which has to carry certain loads ; and although sometimes the difficulty might be overcome by a lavish expenditure of money, the engineer is not always master of the situation. One of the most frequent difficulties is that arising from the levels, and certain forms of structure become necessary which could be avoided if the engineer had free scope in his design. Where an engineer is not restricted by secondary considerations or vested interests which limit his choice of design, it will generally be found that the form of bridge which is—constructionally—best suited for the purpose in view, is also the most appropriate in appearance, except in the opinion of those who would banish iron and other modern facilities altogether. An arched bridge may, in a city, if æsthetic reasons prevail, be often substituted with advantage for a girder bridge, even where the construction of artificial abutments will involve an expenditure of money not needed for a girder bridge. In regard to appearance, an arched bridge has the great advantage, that while occupying in the centre of the arch but little of the headway below the platform, the parapet is the only part of the structure which projects above it, while the same headway could only be obtained below girders of similar span by having them high above the roadway.

Ornamentation of bridges.

Design limited by levels or vested interests.

Arched bridges. *See Examples* K *and* L.

In cases where girders can be placed below the roadway, the design of the parapet-railing, the lamps, and other supplementary details, may be arranged in very different ways, according to the money at command. An engineer should always be informed whether purely utilitarian considerations are to prevail, or whether some latitude in regard to ornament is to be allowed him.

Supplementary details.

Lamps and parapets.

The circumstances which determine the choice of system in bridge-building are so various, and produce such numerous combinations, that designs can seldom be exactly repeated, and it is for this reason that bridges cannot conveniently be tabulated in regard to form, dimensions, weight, and cost in the manner common with other engineering manufactures, such as steam-engines or machines, which, being self-contained and almost independent of site, are catalogued with precision. In a country like England, intersected by numerous roads, railways, canals, and navigable rivers, the engineer in designing a new bridge has the choice of form or system greatly narrowed by the numerous vested interests which prevail, and which demand a conformity to levels and other conditions which he cannot escape. In new countries, the engineer is free from many of these restrictions, and can choose a design best suited to the interests he has immediately in view; and can especially do so where the Government of the country assists by granting facilities or immunities. Not only, however, is there free scope for design in such cases, but economy may be often obtained by making of similar type and span numerous bridges: the roads and other works that follow after being made to conform to the bridges which precede them.

Designs seldom repeated.

Freer scope in new countries.

It is not, however, attempted here to classify bridges according to any scientific method, but rather to show that there are certain rules enforced by the exigencies of the sites which apply to all kinds of bridges. To show clearly the variety in design which prevails to meet different cases, the following eighteen examples of bridges have been selected, each of similar span, but fulfilling very different requirements; and not only might this list be greatly extended, but, as will clearly appear from the nature of the differences, might be interwoven, combined, and multiplied without difficulty into one hundred or more variations. It will be seen that the position of the superstructure in relation to the level of the roadway is the point of view from which the different bridges are classed; and according to such a method, therefore, the cross-section rather than the elevation of the bridges is the primary point to be considered. In regard to the form of elevation, there is a variety too great to be enumerated here, and only some of them are incidentally referred to in the following list.

Variety illustrated by examples.

Classification by cross-sections.

The wrought-iron used in England for bridges is of a quality equal to a breaking strain of from 18 to 25 tons per square inch, according to circumstances. In the following examples a quality equal to 20 tons has been assumed, and a working strain of 5 tons under the maximum load.

Assumed quality of iron.

See IRON *and* STEEL *in Part II.*

The cost of an iron bridge of course varies according to the current price of iron; and in the following Examples, while the different systems of construction would, in regard to cost, not alter much in relation to each other, the actual price of any bridge at a particular time would depend upon the prices then current for iron. During the ten years ending 1877 the prices of iron have varied 100 per cent., but avoiding extreme and exceptional rates, a cost to the bridge-builders of £4 per ton for pig iron, and £10 for rolled iron plates, has been assumed as a basis in the prices given in the following Examples. The cost includes the carriage to the port of shipment in the country of manufacture, but does not include the cost of erection on the site. From £2 to £5 per ton are limits which will embrace the cost of erection in the great majority of cases, the exact cost being determined by the nature of the site, the need of staging, the difficulty of fixing staging, the cost of labour, and other similar circumstances. The Examples treat only of the superstructure, as the piers are even more dependent on local circumstances, and must be treated accordingly.

Cost of bridges depends on current price of iron.

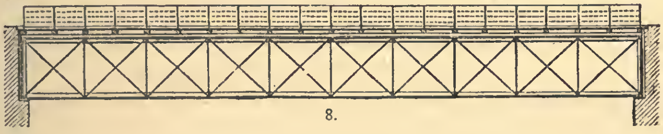
See FLUCTUATIONS IN PRICES *in Part II.*

Cost of erection.

Examples of 100 ft. spans.

Foot-bridge 6 ft. wide.

Example A.—A bridge 100 ft. span and 6 ft. wide, for carrying foot passengers or beasts of burden, equal to a moving load of 80 lbs. per square foot. The bridge is composed of two main girders 10 ft. deep, placed 5 ft. apart, and braced together below the platform.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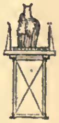
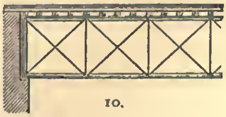

9.

Cross beams of timber, bolted on to the girders at intervals, support a platform of longitudinal or diagonal planking. A light wrought-iron railing is fixed at each side. The ironwork would weigh about 10 tons, costing about £20 per ton.

Single-line railway bridge.

Example B.—A bridge 100 ft. span and 10 ft. wide, for carrying a single line of standard-gauge railway equal to a moving load of 1½ tons per lineal foot. The bridge is formed of two main girders 10 ft. deep, placed 5 ft. apart, and braced together; cross beams of timber supporting the longitudinal sleepers, to which the rails are spiked. Longitudinal planking between the rails serves as a footpath; guard-timbers are placed along the edge of the platform, but there are no parapets. The ironwork would weigh about 24 tons, costing about £18 per ton.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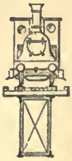
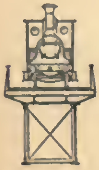

11.

Single-line railway bridge.

Example C.—A bridge 100 ft. span and 14 ft. wide, for carrying a single-line standard-gauge railway, equal to a moving load of 1½ tons per lineal foot. The bridge is formed of two main girders 10 ft. deep, placed 8 ft. apart, and braced together. Iron cross-girders are placed 10 ft. apart, and attached to them are iron longitudinal rail-bearers, supporting cross-sleepers of timber 2 ft. 6 in. apart, to which the rails are attached in the ordinary way, by chairs or spikes. Between and outside the rails a deck or platform of planking is provided, and there is a light parapet-railing. The ironwork would weigh about 38 tons, costing about £17 per ton.



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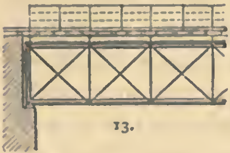
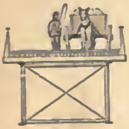


13.

Highway bridge 18 ft. wide, with timber roadway.

Example D.—A bridge 100 ft. span and 18 ft. wide, for carrying highway traffic equal to a moving load of 80 lbs. per square foot. The bridge is formed of two main girders 10 ft. deep, placed 14 ft. apart, and braced together. Upon iron cross-girders 5 ft. apart a platform of longitudinal planking 4 in. thick is placed, and there is an upper surface of wearing planks, which can be renewed when required. A strong iron parapet-railing is fixed on each side. The weight of ironwork would be about 36 tons, costing about £17 per ton. In a bridge of this kind the longitudinal planks should be laid with 1 in. space between them, so that the air can circulate; and if the timber is of good quality, such a platform will last for many years in any but an exceptionally destructive climate. A bridge of this description is not only strong enough to sustain an average load of 80 lbs., but the concentrated load of a waggon with 5 tons on each pair of wheels. It would not be strong enough to carry a heavy traction-engine safely.



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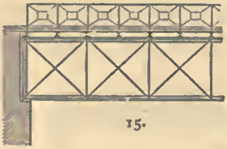
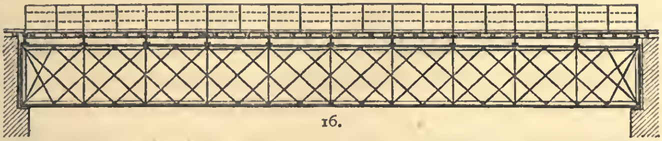


15.

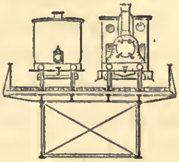
Double-line railway bridge.

Example E.—A bridge of 100 ft. span and 26 ft. wide, for a double line of standard-gauge railway, equal to a moving load of 3 tons per lineal foot. The bridge is formed of two main girders 10 ft. deep, placed 16 ft. apart, and braced together. Iron cross-girders are placed 10 ft. apart, and attached to them are iron longitudinal rail-bearers; and on the iron framework thus composed are cross timbers or sleepers, to which the rails are spiked, and there is also a complete deck of planking. The timber alone would impose a weight of about 25 lbs. per square foot, or 650 lbs. per lineal foot of bridge. On each side of the bridge is a light wrought-iron railing. The ironwork would weigh about 70 tons, costing about £17



16.

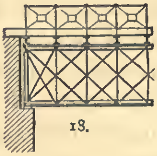
Weight of wide and narrow bridges compared.



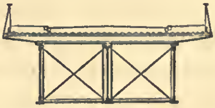
17.

per ton. A bridge of this kind, as compared with a similar bridge half the width for a single-line railway, requires main girders stronger and heavier approximately in a similar proportion, *i.e.* double that of the narrower bridge; but the cross-girders, being of longer span, would be more than twice as heavy as in the narrower bridge. The alternative plan, therefore, presents itself of having three or four main girders instead of two, and so reducing the span between the bearings of the cross-girders. There are, however, certain parts of the main girders which cannot in practice be reduced in weight exactly in accordance with the diminution of the loads, and therefore some of the saving effected in the cross-girders would be lost in the additional weight which the three or four light main girders would have as compared with the weight of two main girders. Each case must be considered on its own merits according to the span, the loads, the depth of girder, and other circumstances.

Highway bridge 32 ft. wide with macadam roadway.



18.



19.

Example F.—A bridge 100 ft. span and 32 ft. wide, for carrying heavy highway traffic equal to a moving load of 100 lbs. per square foot. The bridge is formed of three main girders 10 ft. deep, placed 11 ft. apart, and braced together; and resting upon them are iron cross-girders 5 ft. apart, which project as cantilevers to carry the footpaths. A platform of corrugated iron plates, riveted to the cross-girders, carries the road macadam, which is 4in. thick on 8 in. of concrete, the plates and the road material together imposing a dead load of about 160 lbs. per square foot on the bridge. On each side is fixed a strong iron railing. The bridge could be divided into a carriage way of 18 ft. to 20 ft., sufficient for two lines of vehicles, and two footpaths of 6 ft. to 7 feet; asphalte ¾ in. thick on the concrete being substituted for macadam

See in Part II. CORRUGATED IRON.

at the footpaths. A moving load of 100 lbs. per square foot of the entire surface being assumed, the local supports are also strong enough to allow a traction-engine to pass safely if a maximum load of 10 tons on any one pair of wheels be not exceeded. The weight of iron in the bridge would be about 106 tons, costing about £17 per ton.

Roadway above the girders generally preferable.

The foregoing Examples, A to F, are alike in having riveted girders of the trellis or lattice kind; in having a depth one-tenth of the span; and in having the roadway upon the upper part of the girders. This mode of placing the roadway is that usually adopted where circumstances permit; and it may be taken as the best and simplest method according to the English system, although the want of headway below the bridge often forbids its adoption.

Deep girders allow saving in weight.

Deep girders usual in America.

See page 120.

A saving in weight may, however, be obtained by making the girders more than one-tenth of the span, and, on the other hand, there are often cases where, because of the limited space below the bridge, the depth must be less than one-tenth of the span. The practice of making deep girders prevails in the United States more than in England, because the pin system of construction is more suitable for deep girders than the riveted system. Girders with a depth of one-seventh, and even one-fifth of the span, are made in America, but while the saving in weight thus obtained may allow economy in transport, the cost at the factory is about the same, the more expensive workmanship of the pin system balancing the saving in material. Moreover, in the opinion of many engineers, such bridges are not so permanently serviceable as are riveted girders, which in England are seldom made deeper than one-eighth of the span.

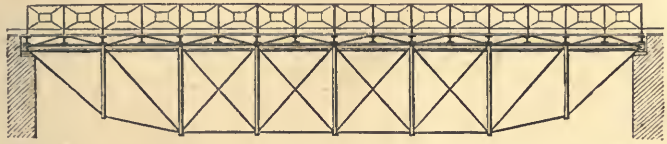
Shallow girders.

Deflect more than deep girders.

Girders are frequently made of a depth much less than one-tenth of the span; one-twelfth is very common, and from one-fifteenth to one-twentieth were considered proper proportions in the earlier days of iron girder-making. Proportions of 1 in 15 are still occasionally adopted, and 1 in 20 may be taken as the limit even for continuous girders. Shallow girders require a greater expenditure of material than deep girders of equal strength, and such abnormal proportions are only adopted where the exigencies of the site demand them. Moreover, even when the same strength as represented by the load-carrying capacity is given, a shallow bridge is less rigid, and deflects more than one with a well-proportioned depth.

Plate girders.

Plate-girders (so called from the web being of a solid plate, as distinct from the open lattice or trellis web) are generally preferable for spans up to about 100 ft., where the depth is limited to 1 in 15, as the greater weight of iron necessary can so be conveniently applied. The three systems would then compare approximately as follows, if applied to a bridge of width, platform, and load-carrying capacity the same as Example F.


20.

Deep truss girders.

Example G.—A bridge with three pin-connected trussed girders, 14 feet deep, placed 11 ft. apart and braced together, would weigh about 90 tons, costing about £20 per ton.

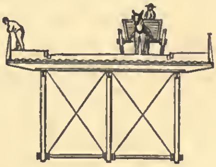
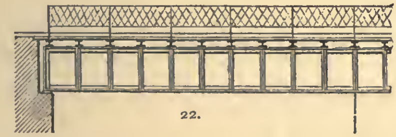

21.

Plate girder bridge.

Example H.—A bridge of similar width and strength, but composed of three plate girders, 7 ft. deep, would weigh about 110 tons, costing about £18 per ton. Where, however, the headway below a bridge is so limited as to forbid the use of girders of economical proportions, the necessary strength may generally be best given, as in Example J, by numerous girders placed near together, requiring no cross girders.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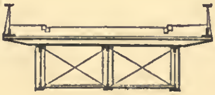
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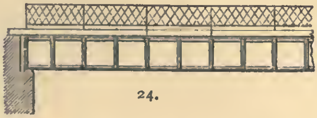
Highway bridge 32 ft. wide without cross-girders.

Example J.—A bridge 100 ft. span and 32 ft. wide, for carrying highway traffic. The bridge is formed of seven main girders, 5 ft. deep, placed 5 ft. 4 in. apart, and braced together. There are no cross-girders, but a platform of wrought-iron plates is riveted directly to the top flanges of the main girders, of which, indeed, they form to some extent, by such an arrangement, an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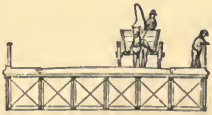
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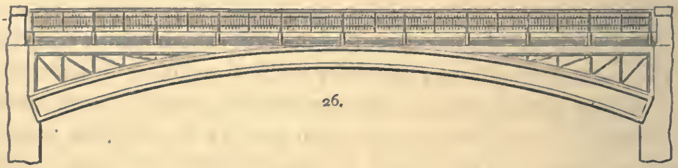
effective part. The roadway material, the parapets, and the strength of the bridge per square foot, are similar to those in Examples F, G, H. The weight of iron would be about 175 tons, costing about £16 per ton. It will be observed that in a bridge of this kind the depth or thickness of the structure is kept down not only by the moderate depth of the main girders, but by the absence of cross girders.

Arched bridges allow maximum headway.

Still within the class of Bridges which have the roadway above the structure, an arched bridge, as in the following Examples K and L, allows the minimum depth of parts below, if a cross-section only at the centre of the span be considered; and if the headway below be needed for the passage of masted vessels, sufficient height at the centre of the arch alone is necessary. If, however, the height of the headway below the bridge is determined, not by the height of masted vessels, but by the level of flood-waters which must pass, or of floating ice or trees, headway in the centre only of the arch would not be sufficient; and it is besides undesirable that the springing of the arch should ever be below the water, though the arch would leave sufficient headway if unmasted boats only have to pass, and if the flood waters reach only to the level of the springing.

Wrought-iron arched bridge.

Example K.—An arched bridge 100 ft. span, and 32 ft. wide, for carrying highway traffic equal to a moving load of 80 lbs. per square foot of surface, or a vehicle having as much as 8 tons on one pair of wheels. There are seven main ribs of wrought-iron, having a depth of 2 ft. 6 in. (one-fortieth ot the span) at the crown of the arch, braced together transversely by lattice frames. The platform is made of 6 in. planking, laid transversely on the arches, with wood roadway blocks, 4 in deep, bedded on the planks in asphalte. The carriage-way is 20 ft. wide for a double line of vehicles, and there are two footpaths, each 6 ft. wide, of narrow oak planking. The parapets are formed of wrought-iron railings, with cast-iron standards. The iron-work would weigh about 65 tons, costing about £19 per ton.



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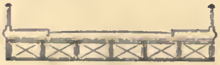


27.

Cost of abutments must be reckoned.

In comparing the cost of a bridge of this sort with that of a girder-bridge, the abutments must of course be taken into account. In an arched bridge the abutments must be stable enough to resist the horizontal thrust of the structure, and not, as in a girder bridge, a vertical load only, and the cost of the abutments would depend mainly upon the suitability of the soil for foundations, and the cost of building materials.

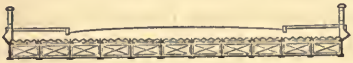
Cast-iron arched bridge.

Cast-iron roadway plates.

Heavy road material.

Cast-iron arched railway bridges.

Example L.—An ornamental cast-iron arched bridge, 100 ft. span, and 53 ft. wide, suited to carry the heaviest street traffic of a city, a moving load of 100 lbs. per square foot being assumed, the bridge being also strong enough to carry a traction-engine or a steam-roller of the heaviest kind made up to 1877. There are twelve cast-iron main ribs, each formed in three pieces bolted together, and 2 ft. 6 in. deep at the crown of the arch, the ten inner ribs being of a plain **I** section, and the two outer ribs having bold mouldings and ornamental spandril-fillings. Transverse bracing-frames of cast-iron connect the main ribs, and support a platform of cast-iron corrugated plates, bolted together and made water-tight by caulking. The carriage-way is 35 ft. wide, sufficient for four lines of vehicles, the road being formed of granite blocks 8 in. deep, bedded upon concrete. The footpaths are each 9 ft. wide, formed of stone slabs on concrete, the dead weight of plates, concrete, and paving averaging 300 lbs. per square foot over the entire surface of the bridge. On either side there is a strong parapet of ornamental cast-iron. The weight of ironwork would be about 420 tons, and the cost about £12 per ton. The cost of decorative painting or gilding and of lamps is not included above, nor in any of the previous Examples. As a considerable part of the cost would be incurred for patterns and special preparations, the cost per ton would be reduced by 2 to 10 per cent. in a bridge with two or more similar spans, as these expenses would be divided over a larger tonnage. Cast-iron is the material best suited for an iron arched bridge with a heavy dead load as in this Example and—except where the cost of transporting the heavier weight and the risks of breakage during transport are very serious—is superior to wrought iron, because while sufficiently elastic, it is stronger against compressive strains, and is less liable to deterioration by rust. That is to say, the weight and stability of cast-iron is specially suited to heavy roadway material and heavy traffic. Cast-iron in an arched



28.—CROSS SECTION.

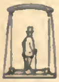
form is often employed for railway bridges, except in very cold countries, where, during extreme frosts, it is considered liable to fracture under percussive loads.

Bridges with the roadway on the lower part of structure.

Following the classification adopted on page 132 of bridges designed to meet the exigencies of levels, all the preceding Examples belong to the category of bridges with the roadway on the upper part of the structure. The Examples that now follow belong to the second category, of bridges with the roadway on the lower part of the structure—a system seldom preferred except when the limited headway under the bridge forbids the opposite system. For where the girders are above the platform it is obviously impossible to brace between them, unless the bracing can be placed high enough to be clear of the traffic on the roadway. In cases where the girders are not high enough to allow this, they must be stiffened in some other and generally more expensive way. As it is generally necessary in bridges of this kind that the main girders shall be the full width of the roadway apart, the span of the cross girders is greater than when they can (as in Examples A to H) be made to overhang the main girders, so reducing the span between their bearings, and consequently their weight and cost. Against the cost thus incurred in bridges of this kind, must be set the saving in parapets allowed by the girders themselves serving for that purpose.

Foot bridge 6 ft. wide.

Example M. — A bridge 100 ft. span and 6 ft. wide for foot passengers or beasts of burden, equal to a load of 80 lbs. per square foot. The bridge is formed of two main girders 10 ft. deep, braced together at the top. Resting upon and riveted to the bottom flanges of the main girders, or suspended to them by bolts, are **T** or **I** irons, serving as cross-girders, on which are placed longitudinal timbers, to which a plank floor is nailed. The main girders are made serviceable as parapets by the addition of twisted wire ropes, as indicated by the dotted lines. The weight of iron would be about 12 tons, costing about £20 per ton. Foot-bridges, with the roadway on the lower part of the structure, are often made with bow-string girders, but the parallel girders can be more conveniently held at the ends.



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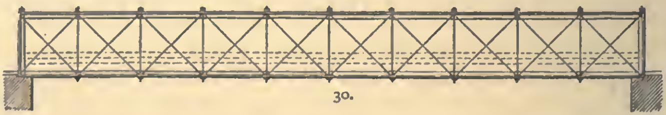
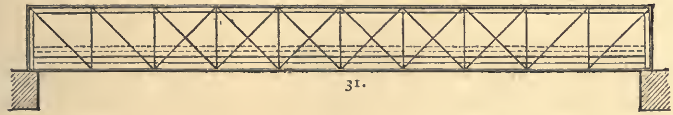


30.

Single-line railway bridge.

Example N.—A bridge 100 ft. span and 14 ft. wide for carrying a single line of standard-gauge railway equal to a moving load of 1½ tons per lineal foot. The bridge is formed of two main girders 10 ft. deep, and iron cross-girders. The rails are carried on longitudinal iron bearers attached to the cross-girders, which also sustain a complete deck of planking. There is wire-rope railing, as in M. The weight of iron would be about 40 tons, costing about £17 per ton.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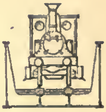
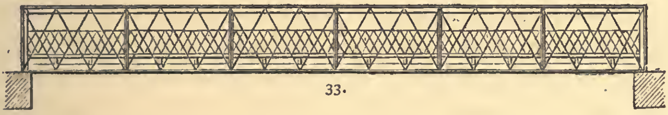

32.

Highway bridge 18 ft. wide.

Example O.—A bridge 100 ft. span and 18 ft. wide, for carrying highway traffic equal to a moving load of 80 lbs. per square foot, or a vehicle with 5 tons on each pair of wheels. The bridge is formed of two main girders 10 ft. deep, lattice work being added to serve as a parapet railing. The roadway is formed of longitudinal planking laid upon iron cross-girders, and there is an upper layer of wearing planks placed transversely. The weight of ironwork would be about 38 tons, costing about £17 per ton. There is little difference in weight between this bridge and Example D, as the cross-girders, though longer in span, have not a heavy weight to carry as in a railway bridge, and there is therefore little scope for saving weight.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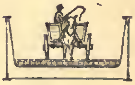
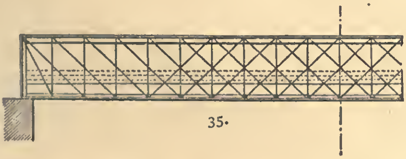

34.

Double-line railway bridge.

Example P.—A bridge 100 ft. span and 26 ft. wide, for carrying a double line of standard-gauge railway equal to a moving load of 3 tons per lineal foot. The bridge is formed of two main girders 10 ft. deep, and a platform is made of cross-girders placed 10 ft. apart, longitudinal rail-bearers, and planking, as in Example N. The weight of iron would be about 85 tons, costing about £18 per ton.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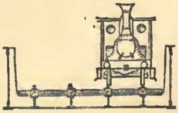
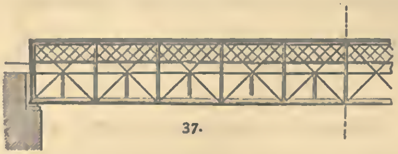

36.

Highway bridge 30 ft. wide.

Example Q.—A bridge 100 ft. span and 30 ft. wide for carrying highway traffic equal to a moving load of 80 lbs. per square foot, or 8 tons on a pair of wheels; the width allowing for a carriage-way of 20 ft., and two footpaths of 5 ft. The bridge is formed of two main girders 10 ft. deep, and iron cross-girders placed 5 ft. apart. The platform is composed of planks 6 in. thick laid longitudinally on the cross girders, and wood roadway blocks 4 in. thick are bedded in asphalte on the planking. If 2 ft. 6 in. (one-twelfth of their length) were allowed for the depth of the cross-girders, and 1 ft. 6 in. for the thickness of road material, including packing and curbs, the main girders would still be left as parapets 6 ft. high above the road level. As, however, in a highway bridge it is more convenient to have a parapet of moderate height, that is to say, 4 ft. instead of 6 ft., advantage may be taken of this circumstance (if the levels or gradients of the approaches in their relation to the headway below allow it) to make the cross-girders deeper, and by such an economical application of material to reduce their weight. A depth as great even as one-fifth of the span may be given to the cross-girders; but in the present case they are made 4 ft. 6 in. deep, and the parapet is only 4 ft. high. The ironwork would weigh about 56 tons, costing about £18 per ton.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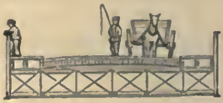
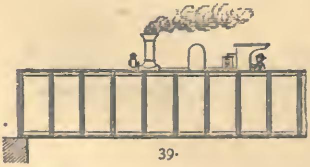

38.

Railway bridge for four lines.

Example R.—A bridge 100 ft. span and 52 ft. wide, for carrying four lines of standard-gauge railway equal to a moving load of 6 tons per lineal foot. The bridge is formed of three plate main girders 10 ft. deep, the centre one having double the strength of the outer girders. The platform is formed of cross-girders, longitudinal bearers, and buckled plates. Asphalte ½ in. thick and ballast 12 in. thick are laid upon the plates, and the rails are attached to longitudinal or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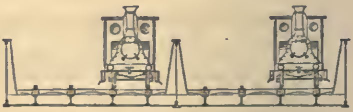

40.

cross sleepers, according to the system of permanent way usual on the railway, this method being preferred by many engineers. The plates, ballast, sleepers, and rails would together impose a weight of about 140 lbs. per square foot on the bridge. The ironwork would weigh about 250 tons, costing about £16 per ton.

Intermediate girders objectionable for highway bridges

A bridge with a wide roadway constructed in this way compares favourably in weight and cost with one in which only two main girders are employed, as cross-girders spanning the whole width of the platform, without intermediate support, would be heavy and expensive. Highway bridges are not so often made with three main girders in this way, because a raised girder in the centre of the road is objectionable, except in cases where it can be utilised for dividing the lines of traffic But where owing to the levels of the approaches and the amount of headway required below the bridge, cross girders spanning the whole width would by their depth so raise the height of the platform as to render the gradient of the approaches excessive, intermediate main girders become necessary, thus dividing the roadway into avenues, the ends of the central girder being protected by guard-posts and lamps. In cases where a considerable proportion of the bridge is devoted to footpaths, the span of the cross girders may be kept sufficiently short with only two main girders by carrying the footpaths on brackets outside the girders, thus leaving the carriage-way undivided.

Overhead bracing for deep girders.

Headway necessary below bracing.

Referring to the summary remarks on page 136, concerning Examples A to F, it may now be observed that Examples M to R are alike in having riveted girders of the trellis or lattice kind; in having a depth one-tenth of the span; and in having the roadway on the lower part of the structure. Girders deeper than one-tenth of the span allow, as has already been said, a saving in weight, but in the case of bridges like those which have just been described, such girders to be effective must be deep enough to allow overhead bracing without obstructing the roadway. But except in bridges of moderate width, the distance to be spanned by the overhead bracing renders its use difficult or practically impossible; and if deep girders are made without overhead bracing, the expense and inconvenience of stiffening them in some other way greatly reduces the saving otherwise obtained. A headway of from 14 ft. to 16 ft. is generally considered necessary for the passage of loaded vehicles; a locomotive of standard gauge measures about 13 ft. 6 in. to the top of the funnel; a passenger tram-

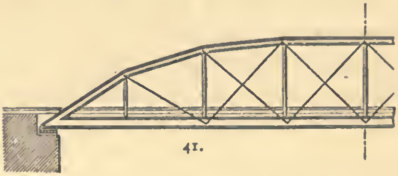
TRAMWAYS.

car measures from 10 to 11 ft. from the ground to the top rail of the roof, and for outside passengers standing up on such a car, 14 ft. 6 in. would be necessary. The Board of Trade regulations for bridges in England prescribe a headway of 16 ft. for highway traffic under railway bridges. But for overhead bracing on highway bridges, conditions of headway may be, and frequently are, relaxed, and where a clear headway of 14 ft. is afforded, overhead bracing may generally be permitted. As the trussed girders on the pin system which are in favour in the United States are made as deep as one-eighth or even one-fifth of the span, space for overhead bracing is obtainable in spans much less than according to the English system of girders, one-tenth of the span.

The following Example shows deep riveted girders of a kind sometimes employed in England.

Double-line railway bridge.

Example S.—A bridge 100 ft. span and 26 ft. wide, for carrying a double line of standard-gauge railway equal to a moving load of 3 tons per lineal foot. The bridge is formed of two wrought-iron main girders 14 ft. deep of the bowstring kind, this name being given to girders with a curved upper flange and a horizontal tension member. In the present case the upper member is polygonal, as allowing a cheaper application of the iron than if it had to be cut or bent to a curve. Under most conditions of loading, girders of this shape can be made with less material than parallel girders, but where the loads to be carried are light, there is little if any economy in practice. The depth of the main-girders also allows a reduction in the weight. Iron cross-girders are placed 13 ft. apart; there are also longitudinal rail-bearers, and the platform is made as in Examples N and P. The ironwork would weigh about 86 tons, costing about £19 per ton.



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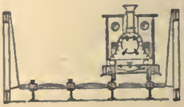


42.

Deep girders.

The necessity for girders less than one-tenth of the span does not arise in the present category of bridges in the same way as with those previously described, since it may be assumed that there is unlimited space above the platform of a bridge. But deep girders are often considered unsightly; they may obstruct light and air; and they present a great surface to the wind. In cases where considerations such as these prevail, and also where (to obtain short-span cross girders) numerous main girders are used, then a depth of less than one-tenth may be adopted.

Deep girders sometimes objectionable.

As arched bridges have been cited as the kind which allow the minimum depth of parts below the platform in the centre of the span, so, in the present category, suspension bridges might be said to allow the minimum height of structure above the roadway in the centre of the span.

Suspension bridges.

In the foregoing examples the span of 100 ft. has excluded suspension bridges, which are seldom used for spans less than 100 ft.; and the advantages they afford—except sometimes for very light footbridges, or when the difficulties in erecting a girder bridge are very great—commence generally only when a span of 200 ft. is reached. As an arched bridge depends for its stability on its abutments, so a suspension bridge depends on the anchorage of its chains; and the suitability in this respect of the site and available building materials greatly determines the cost or expediency of such a bridge. The ordinary suspension bridge, in which the platform is suspended from a catenary chain, is necessarily less rigid than a girder or arched bridge, and while the undulatory movement under moving loads of a platform thus suspended does not render it unsafe for ordinary highway traffic, it makes such bridges unsuited for the passage of railway trains, except in the case of very long spans—over 1,000 ft., where the great weight of the structure gives a stability less susceptible to the impact of such a load as a railway train; and with some additional stiffening a suspension bridge of more than 1,000 ft. span, if strong enough for highway traffic, would carry a railway also. But there have been various improvements in suspension bridges, mainly in the direction of increased rigidity, and, by the combination of other systems of construction, suspension bridges are designed rigid enough for railway traffic. Suspension bridges can be erected from the shores of a river or ravine without the need for temporary staging or any other intermediary support from below; and it is the facilities afforded in this respect, rather than any economy in the cost of the structure itself, which in very many cases justify the choice of a suspension bridge rather than a girder bridge.

Suspension bridges for railways.

See VIGNETTE *on page 111.*

Combined structures. There are various combinations which may be adopted to meet particular cases, and the girder and arch or the girder and suspension systems are examples of such combinations. It may be stated generally that for bridges of a span exceeding 100 ft., there are almost always circumstances which render special treatment necessary, and it is only for small spans that the designs of previous bridges are exactly applicable.

Spans above 100 ft. require special designs.

Opening bridges. Opening bridges are often required to allow the passage of masted vessels, and sometimes they are provided to meet the demands of local authorities or river conservators, even where only a remote future necessity is the reason. Opening spans may be made most easily in girder bridges, as when made in an arched bridge, the pier which is isolated from the shore while the bridge is open has to be made strong enough as an abutment to withstand the lateral pressure of the arches. In a suspension bridge an opening for the passage of vessels can be made in the tower, as in the case of the bridge over the Seine at Rouen; but openings in suspension bridges are expensive, and are to be avoided when possible. When bridges have to be opened frequently (as is the case at the entrance to a dock), the apparatus must allow rapid movement, and the modern system of hydraulic machinery is that most usually adopted for the purpose.

Hydraulic opening apparatus.

To enable an engineer to design a bridge which will best fulfil the purpose in view—to satisfy at the same time the varying exigencies of transport, site, and climate, and to allow a contractor to estimate correctly the cost—information of the kind described on the following pages is necessary. It will be seen that the particulars enumerated include those for a great variety of cases, and those applicable to any particular case must be selected accordingly. Moreover, as many of the particulars are necessary only to the design, these may be omitted where it is intended only to furnish a contractor with information sufficient for estimating the cost of erecting in its place a structure which is already designed.

Information necessary to a design.

Plan of site. 1. A plan of the site showing the position of the bridge in relation to the river (or other space to be crossed) and the approaches, and whether the bridge is to cross at a right or a skew angle. If the number and length of spans have been determined, the positions which have been selected or which appear most favourable for the piers and abutments, should be indicated.

Cross-section showing levels.

2. A cross-section of the site, showing the level of the roadway of the proposed bridge; that of the approaches; and also of the river, road, ravine, or railway, which the bridge is to cross. If a river, the various levels of tide or flood should be marked, so as to indicate the headway available at different seasons below the bridge. These circumstances determine largely what system of superstructure can be applied, and to gain sufficient headway it sometimes becomes expedient to raise the bridge to a higher level than that otherwise necessary. The designer—if free scope be not allowed him in these respects—must be informed of the maximum gradients which will be allowed on the bridge and approaches.

Gradients on approaches.

3. If piers or abutments have to be built, the nature of the ground must be stated, and this can be conveniently done upon the cross-section referred to above, which should include also a profile of the river-bed from shore to shore, showing the slope of the banks and the various strata down to a firm foundation. If the strata are not known with sufficient certainty from previous experience, or from trustworthy borings in the neighbourhood, it will be necessary to make trial borings in the river-bed to ascertain the facts correctly. The cost of such investigations will be always amply repaid by the help they afford to the designer, who can only, when thus informed, make the supports of the bridge of a suitable form and strength. Moreover, having thus ascertained the kind and probable cost of the foundations, he can weigh the advantages of numerous piers and short spans against the opposite advantages of few piers and long spans. In connection with the foregoing particulars, the strength and direction of the water current should be described, and, if the river be navigable, the nature of the boats or vessels, including the heights of their masts, which will pass below the bridge. Mention should also be made of any floating trees or ice which the piers and abutments may have to withstand, and as to how far, in time of flood, such obstructions might reach up to the superstructure.

Nature of the river-bed and banks.

Strata proved by borings.

Passage of vessels

Floating trees or ice.

Too often when the information is furnished to the engineer from a distance, the particulars supplied on these points are so meagre that he is unable to make the most appropriate design, and not daring to run risks which an assumption of unknown facts would involve, gives an unnecessary strength and margin of safety to the supports. A mere statement that the bed of the river is sand, mud, or rock is not sufficient, unless the firmness and depth of the stratum be also described, for these facts alone can determine not only the kind of

Information often too meagre concerning foundations.

supports but the depth to which they must penetrate, and the area of base necessary. Sometimes no information whatever is furnished on these points, but a mere direction only is given that the bridge is to be supported on cylinders or screw-piles, although it should be obvious that the form of screw-piles, or of any other supports, and their length from the superstructure downwards, will depend entirely on such particulars. Even where one span only is required, and where no piers or abutments have to be built, information in regard to the suitability of the river-bed for pile-driving should be stated, if staging is to be employed for the erection of the superstructure.

Pile-driving.
See PILE-DRIVERS *in Part II.*

Prescribed loads.
See DIAGRAM *on page 129.*
Description of vehicles.
Opening bridges.

4. The load which the bridge is to sustain, and the margin of safety required, should be given. If a railway bridge, either a prescribed load per lineal foot should be stated, or a description given of the heaviest locomotive likely to run on the line, including its weight, extreme length, length of wheel-base, and maximum weight on any one pair of wheels. If a highway bridge, the kind and frequency of the traffic, and such a description of the heaviest loads that must be provided for, that the weight concentrated on a pair of wheels, or on a wheel-base of certain area, may be calculated. If openings are required in a bridge to allow the passage of vessels, the kind and maximum size of vessel should be stated, and also whether the vessels may be expected to pass frequently or rarely. By this latter circumstance the kind of opening apparatus will be largely determined.

Exigencies of transport.
Erection on site.
See also page 115.
Local information.
See also page 70.

5. The exigencies of transport which may require the division of a bridge structure into pieces of a certain size and weight; the special circumstances which may render easy or difficult the erection on the site; the kind of workmen who are obtainable; the building materials available and their prices—must all be sufficiently described. In regard to timber, its kind must be described, so that its suitability for staging and decking may be known.

Minor circumstances.

6. There are other and minor circumstances which also affect the cost of a bridge, and concerning which sufficient particulars must be furnished to the designer. Such, for instance, are the degree of ornamentation desired; whether parapets or only mere railing is required; whether lamps are necessary; whether side-walks are wanted, and if so their width; and whether provision is to be made for taking water or gas mains over the bridge.

Terms of concession.
See page 112, and also Chapter II.

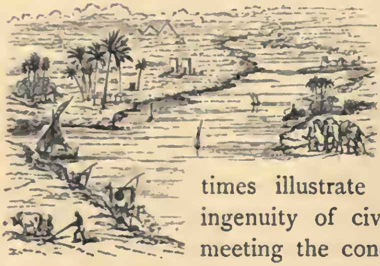
7. If a bridge is to be erected in virtue of a concession, the terms and conditions must be fully set forth. If the payment is to depend in any way upon a revenue from tolls, the calculations of expendi-

ture and revenue, and the data upon which they have been based, must be furnished. If the bridge has to satisfy some specification of quality, or be officially inspected, the standard of quality or the nature of the tests should be described; and also whether the iron is to be subjected to trials, and, if so, their nature, or whether a certain kind, or brand of iron, or guarantee will be sufficient. **Official tests.**

[*See also* CONCESSIONS: LANDING-PIERS. *And in Part II.*, IRON AND STEEL: PUMPS: DIVING APPARATUS: PILE-DRIVERS: PORTLAND CEMENT.]

CHAPTER VIII.

IRRIGATION. RECLAMATION OF LAND.



Irrigation.

IF public works were classed in order according to their antiquity, those of irrigation would justly hold one of the first places. The systems of irrigation adopted in ancient times illustrate in a very striking manner the ingenuity of civilised or half-civilised races in meeting the conditions of soil and climate under which they lived; but besides the interest naturally excited by such ancient works, much valuable information is afforded by them even to the modern engineer, who may, for instance, investigate with advantage the extent of surface irrigated from certain sources of supply; the amount of animal or other power that must have been expended in raising water to irrigate a certain breadth of land; and the periods during which such works have remained in an effective condition. It is also interesting to examine the modes by which irrigation works were rendered financially successful under conditions apparently so insecure that at the present time they would forbid the investments of labour and money; and also the reasons why such works may have failed.

Ancient works.

Investigation of ancient methods.

Irrigation works defined.

Irrigation works comprise the collection, control, distribution, and application of large quantities of water, and the best and most economical methods have to be determined under conditions that vary in every locality. Local irrigation on a small scale is a matter rather for the agriculturist than the engineer, and in all but the most uncivilised countries advantage is taken of adjacent water supplies by owners or occupiers of land. Even in small works of this sort there are different systems, depending on the nature of the supply, the contour of the ground, and the kind of crops. An English water-meadow, a Swiss valley, and an Indian rice-field afford examples of local irrigation still conducted according to the traditional methods in use centuries ago. It is, however, where large works are required—where water has to be brought long distances, pumps erected, rivers embanked, canals or aqueducts constructed, and water stored—that the assistance of the engineer is called for. The difficulties which have been overcome, and the problems which have been solved, in connection with important irrigation schemes of this description, are among the most conspicuous examples of successful engineering enterprise.

Local irrigation.

Large works.

The designing of irrigation works depends on natural and local circumstances as much as, if not more than, any other branch of engineering, and for this reason personal inquiry and examination of the fullest kind must be made on the spot by the engineer. The engineers who can best carry out these works should not only have personal experience of previous works, but be acquainted with what has been done by others under various conditions. Experience of hydraulic works is particularly necessary, and a knowledge of other sciences—such as meteorology, geology, agriculture, and even chemistry—is also wanted; though information on these points from those locally and technically conversant with what is necessary to produce certain results on land and crops, may make available the engineer's special professional skill.

Special skill required.

The principal irrigation works of modern times have been mostly confined to warm climates, such as those of Egypt, India, China, Ceylon, Jamaica, California, Italy, Spain, Portugal, and the South of France. Accounts of these works, comprising what may be called the literature of irrigation, are available for reference but not always in a convenient form, being often partial and incomplete, and contained in a large number of books, few of which are written in the English language. Not the least useful are the bare records of facts, and the statistics of particular works which have been published in different countries under Government or other official sanction.

Examples of important works.

Irrigation works and projects do not admit of any rigid system of classification; they may, however, be broadly classed in several ways.

Classification of systems.

Classification A, according to whether they require the aid of mechanical appliances on a large scale—for instance, where steam, animal, water, or wind power are necessary—as distinct from those which depend on gravitation alone.

Classification B, according to whether they do or do not involve works of storage to any great degree.

Classification C, according to the nature of the irrigation to be effected.

In Classification C, irrigation schemes may be said to consist of *three* kinds, which, however, cannot be considered as wholly distinct. The

Simple irrigation.

first is occasional irrigation, having for its object a sufficient supply of moisture to the crop under cultivation and the softening of the surface of the soil to facilitate tillage—a method principally adopted in hot and arid countries, and more temperate climates during periods of summer heat and drought. Thus in India in many districts the land must be softened for ploughing, and as the period for this is before the rainy season, irrigation becomes necessary; the

Sedimentary irrigation.

after rains fertilising the seed. The *second* is sedimentary irrigation, what has for its object the fertilisation and improvement of the cultivated soil by the application to it, in a stream more or less continuous, of the natural sediment and the dissolved matters contained in the water, which itself may be assumed to act as little more than a vehicle for carrying and depositing the sediment. This kind of irrigation includes that of rice fields in India and China; the flooding irrigation of Egypt, in which the Nile sediment acts so important a part; the *marcite* and *prairies permanentes* irrigation of Italy; and the water-meadow irrigation of England and other cold and temperate climates. Even where rain is plentiful, the cultivator will often allow the rain-water to run off, preferring the artificial supply for the sake of its fertilising

Sewage irrigation.

properties. The *third* is sewage irrigation, in which the fertilisation of the soil is effected by manure, the water both acting as a vehicle and as a diluent; the objects being in most cases both the riddance

See TOWN DRAINAGE.

of noxious refuse from towns and the securing an increase yield from the soil thus improved. This mode of irrigation has been principally confined to cold and temperate climates.

Different systems combined.

While, then, these three modes of irrigation are perfectly distinct in most cases—the choice being determined by the circumstances that demand one to the almost entire exclusion of the other two—there is no reason why they should not all be employed to an important extent in the same scheme. There are many schemes of a combined description in which irrigation is only one

Irrigation by navigable canals.

of the objects, and sometimes a very subsidiary one. This may be the case when navigation either in the canal of supply, or in the river constituting its source, is of importance; but it is a vexed question how far irrigation and navigation by the same canal can be ever rendered profitable. There are also cases where the question of protection from floods, general drainage, river improvement, land reclamation, or town water-supply, complicate the conditions of the design. When such combinations occur as not only render the irrigation quite subsidiary, but compromise its efficiency and regularity to any great extent, the irrigation profits become very much reduced.

Subsidiary works.

It is necessary in an irrigation scheme to provide not only for supplying the water, but for the disposal of the surplus water. Drainage questions will almost always arise, and should therefore form part of the project from the first.

Drainage of surplus water.

The two sources of return from investments in works of irrigation are, the increased amount of produce and the enhanced value of the land; and it is these that alone can repay all concerned in the undertaking, from the field-labourer on the spot to the investing capitalist at a distance. There are, besides, considerable benefits not directly affecting either the cultivator, the landed proprietor, or the capitalist, which result from the utilisation in trade and commerce of the larger amount of money and produce brought into public use. The local, and sometimes even the national, prosperity due to the impetus thus given by extensive irrigation works is an important advantage, independent of the direct return previously mentioned. The newly-developed trade supports and creates a new population, and taxation then yields an increased revenue to the State. Some of the irrigation schemes promoted and guaranteed by the Government of India can only be justified economically by the indirect advantages they promise, and they have already in many cases fully answered expectations. For instance, in Orissa (India), the development of the country, as shown by the yield from taxation, has been considerable, and the export trade in rice and other seeds has even created a new port. It is for these reasons that national and local governments are enabled to assist such projects by suitable guarantees and concessions; but when once the results of such schemes have been made manifest in practice, it becomes questionable whether concessions or guarantees are any longer expedient, and whether the outlay for new schemes should not be made directly from public revenues, or left entirely to private capitalists without guarantee.

Sources of profits.

Indirect benefits.

National advantages.

Trade and revenue promoted.

Concessions and guarantees.

See Chapters II. and III.

See page 32.

An ably-designed, well-supported, and carefully-executed project of irrigation will, if well managed after it is established, repay its cost by means of its combined direct and indirect benefits. Instead of mere patronage and philanthropic assistance, schemes of irrigation require rather a clear-sighted, thorough examination of all the points affecting them in the first instance, and a persistent adherence to correct principles in their execution, development, and management afterwards. Hence the necessity for able and well-qualified men both in the engineering and in the administrative superintendence of works of this class, and for enterprising and skilful landowners and farmers, who will develop to the fullest extent the improved agriculture rendered possible by irrigation. Irrigation pays best—other conditions being equal—where there is an agricultural population sufficiently large to do full justice to the improved land. Thus the irrigation of rice-fields in some parts of India has been profitable because there is a large population devoted to agriculture, and who look to it for their livelihood without any thought of changing their position. On the other hand, irrigation works executed in sparsely-peopled districts, in the hope that the advantages afforded would bring the surplus population from less favoured districts, have failed, because of the unwillingness of the people to leave their accustomed homes.

Conditions of success.

Able administrators necessary.

Large population advantageous.

Neglected works.

There is nothing which suffers so much from neglect as irrigation works, as the ancient tanks of India, or the arid sides of hills once watered by channels now in ruins, so frequently testify.

Financial success.

The financial success of an irrigation scheme depends, of course, upon the return which can be obtained from a certain outlay. The outlay consists mainly of the purchase of land, the cost of works, and sometimes of compensation for proprietary rights. To this outlay must be added the engineering and legal expenses, and sometimes also the adaptation of the land. In most cases the proprietors are willing to undertake this adaptation at their own expense, their prospective share of profits enabling them to incur the expense as a charge on their estates, and to raise money privately for the purpose, thus in effect reducing the first cost of the project.

Items of cost.

Adaptation of land.

Capital—how to be provided.

Capital may be provided in a variety of ways. In some cases, though rarely, the landowners or occupiers subscribe among themselves according to the extent of their holdings; in others the local or national Government provides the money; and in others it is subscribed by outside capitalists. In the two latter cases the land-owners or occupiers who directly benefit by the irrigation can pay rent for the water in the shape of a water-rate, calculated according to the amount of water they receive or the area irrigated, or they can resign to the Government or capitalists a certain proportion of their land.

Sinking fund.

See page 37.

A sound irrigation scheme generally provides not only for a remunerative return, but for the gradual repayment of the capital itself within a stated term, thirty to forty years being a usual time. In order to recover the whole of the capital within this period, the annual water-rate must be determined accordingly, and a sinking fund provided. By estimating the acreage likely to be irrigated annually, and the supply of water likely to be utilised at various seasons, an appropriate rate either per acre, or per cubic foot per second of supply, suitable to the various kinds of irrigation and descriptions of soil, can be properly fixed. It is, however, evident that the rate must be not only sufficiently high to cover cost, maintenance, and repayment, but also sufficiently low to leave a profit to the land-owners or occupiers. To estimate this, the data enumerated in clauses 6 to 13, on pages 158 and 159, become necessary. If, for example, the non-irrigated land yields £10 per acre clear, and the irrigated land £17, and if the appropriate water-rate determined by the exigencies of the works in the manner already described averages £3 per acre, the profit left to the proprietors, or occupiers, of the land would then be £4 per acre. If this proportion between the water-rate and the profit prove sufficient and practicable, such a division can be arranged; if not, it may be often necessary that arbitration be called in to adjust the figures. Unfortunately, however, in many cases the original capitalists do not realise any profits, and it is left to second or later generations to reap all the advantages.

Water-rate.

Assessment of water-rate.

Land increased in value.

Another source of profit is that due to the increased value of the irrigated area after the irrigation has been established, or, after the period of redemption of the capital has expired, where some of the land originally worthless may have become very valuable, an increment from three to ten-fold being not infrequent. This prospective enhancement of value does not admit of more than an approximate estimate; but, whatever it may amount to, it may be divided or adjusted between the capitalists of the undertaking and the land-owners, in the same manner as the water-rate and the annual profit referred to above. The difficulties which might ultimately attend

Land grants.

this division of the prospective increase of value are frequently settled at the outset by the landowners giving a free grant, or a perpetual or long lease of a certain portion of the irrigable area to the capitalists; this plan not only securing to the latter their just share of benefits effected by the works, but giving to both a common interest in the ultimate success of the scheme; while the water-rate is allowed to cover the actual expenses of the undertaking.

Water-rate made obligatory.

It is not safe to rely on the voluntary use of the water supplied by irrigation, as backward, impecunious, or conservative agriculturists are often slow to adopt new methods, even when provided for them at reasonable cost. Whatever be the arrangement for the payments, the rate of contribution should be assessed beforehand, and rendered obligatory, either by legislative decrees or by voluntary legal engagements.

Division of profits.

Government aid.

See pages 24–33.

In whatever way the redemption of capital and division of profits may be arranged in actual practice, it will be quite evident that no enterprise of this description can prove permanently successful unless everyone in connection with it is allowed to obtain his due share of advantage, and unless all claims are protected by sufficient security. In consequence of the great national advantages resulting from successful works of irrigation, previously alluded to as indirect profits, it is generally to the interest of the Government of the country, or the province in which the works are undertaken, to offer facilities or assistance in the form of capital, concessions, or guarantees for a limited number of years. In some cases, they defray a portion of the expenses of construction, or give grants of land; in others, they will guarantee a certain interest on the capital expended for a term of years until the irrigation can be sufficiently developed to repay its maintenance; in others, again, they cede proprietory or territorial rights and powers for the recovery of claims. Under any circumstances, and more especially in the case of extensive works, a certain amount of Government sanction or countenance is requisite.

Hypothecation of land to capitalist.

In the case of the land being entirely in the hands of private proprietors who wish to make the matter a local one, it will be necessary for them to co-operate either by supplying a portion of the capital, or by hypothecating or making over a portion of their lands on conditions that will afford sufficient security to those furnishing it. This is the mode so successfully adopted in south-eastern Spain by the Moors, who were masters in this appliance. Many most promising schemes of irrigation fail to attract outside capital, because they are projected in countries where legal security is doubtful, and as the returns for irrigation investments are necessarily spread over a considerable period, such lack of security is the most fatal bar to the obtaining of capital.

Insecurity a cause of failure.

See page 51.

The information that serves as the basis of an irrigation project is of two kinds, the one comprising the local conditions from an engineering and an agricultural point of view; the other being of a financial and economic nature. Details of the concessions or privileges that will be granted, of the sources from which the works will be paid for, and other information as to the nature of the engagements contemplated, are indispensable portions of any proposal for the construction of works of irrigation.

Basis for irrigation projects.

The following list enumerates those particulars to which—some or all of them, according to the nature of the case—an irrigation-engineer on the spot would direct his attention. In countries where there do not happen to be any competent resident engineers, the best method is to collect so much of the information enumerated below as is within the means at command, and to place it before a competent engineer in England, who can advise on the *primâ facie* conditions of the case. Some of the particulars enumerated demand the services of a surveyor or engineer accustomed to measuring land and taking levels; others demand geological and meteorological knowledge; while some of the particulars are merely matters of fact which can be ascertained by any person of intelligence in the locality.

Information classified.

1. A plan showing the area to be operated on, with the names of the owners and occupiers marked upon it, and a sufficient number of levels referring to a datum.

Plan and levels.

2. A series of sections on all the more important lines, such as the courses of streams and rivers, the water-sheds, the approximate courses of proposed canals and distributaries; also a series of sections over the sites for storage, if these enter into the design.

Sections.

3. General information as to the natural and physical features of the locality.

Natural features.

4. A full and detailed account of any existing irrigation works in the neighbourhood, even though they be only on a very small scale; with remarks on the difference of conditions between them and the proposed works; and accounts of any neighbouring navigable canals.

Existing works described.

Data for estimating water supply.

5. Data for calculating the amount of natural water-supply available at various points in different seasons: if the source of supply be one or more rivers, then soundings, showing the water level at various seasons in flood and in drought should be given: a demarcation of the limits of areas submerged at various times: the points at which overflows take place: the periods and duration of floods and droughts: the tendency of the river to deposit silt, and the quality and amount of the latter under different conditions and velocities. Should it be intended to take the supply from wells, full particulars of those already existing should be given, as well as regarding the probable depth and copiousness of supply from the proposed new wells, and the geological strata that will most probably be met with in sinking them. Should the storage and collection of surface water, or the interception of streams by dams, be depended on as a source of supply, full information becomes necessary regarding both the geological and meteorological conditions of the catchment area; this should include all available data of rainfall, evaporation, humidity, and absorption. The seasonable occurrence of the rainfall is even more important than a copious supply. In the Orissa famine year (1866) the rainfall was considerably above the average, but it was ill-timed. A description of the superincumbent geological strata, and an account of the mode in which every part of the area is occupied or used, should be furnished.

Meteorological conditions.

Rainfall.

Quantity of water required.

6. Existing examples of the amount of water required for watering, both in the gross at various seasons over the irrigable area and in detail per acre on various soils; and the probable effect on the crops of increasing the supply.

Soil, crops, and systems of tillage.

7. Full information about the irrigable area itself, its various soils, the crops that are and may be grown on it, and anywhere near it, their rotation and probable yield in favourable, average, and unfavourable seasons, and their market value: the systems of tillage in vogue, and the proposed modifications: the trees, shrubs, and plants that are most common, and those growing on the banks of the rivers and near marshes, and the condition of such vegetation, whether thriving or otherwise: the effect on the soil of periodic watering, and long stagnant water: the climate and meteorological conditions of the area to be irrigated.

Materials and labour.
See page 70.

8. The soil in which the proposed works will be carried out: the stone, lime, clay, brick-earth, and timber available, and their cost:

the expenses of transport, and the kind and cost of labour that can be obtained.

9. The kind and cost of fuel which is obtainable for pumping engines: the local opportunities or facilities for pumps to be worked by wind or water power.

Fuel, and power for pumps.

10. A careful estimate of the value of the average yields per acre of non-irrigated land in the neighbourhood, and, secondly, that of the average yield that irrigated land will produce under the proposed system of rotation, after making allowance for unfavourable years and agricultural contingencies. The number of the population, their habits, and capabilities for utilising irrigated land.

Yield of crops per acre.

Population.

11. The communications—roads, railways, and canals—by which the produce of the land can be transported; the proximity to markets, and rates of freight by various routes.

Roads, railways, canals.

12. If sewage-irrigation is contemplated, the kind, richness, and amount of the sewage, the source of supply, and the terms on which it is to be obtained.

Sewage, value of. *See* TOWN DRAINAGE.

13. The tenure on which the land is held; the compensation to be paid for the extinction or lease of proprietary rights; the amount of capital which will be contributed by the landowners, tillers, or by local capitalists; the facilities, assistance, contributions, or guarantees which will be granted by the Government.

Tenure of land.

Government aid.

The Reclamation of Land from the tidal action of the sea, or its recovery from rivers, lakes, or marshes in the interior of the country, is a branch of engineering reintroduced into England in modern times by the Dutch, who, in their turn, in still later times have been indebted to the aid of English engineers and contractors in carrying out such works in their own country on improved principles. Under this general title of Reclamation may be comprised works on any scale, from the filling or draining of a small lake or marsh on a private estate to the "warping-up" (the raising of land by the deposit of sediment from flood or other waters) and enclosure of large tracts of foreshore or estuarial flats.

Reclamation of land.

Improved systems.

Reclamation works defined.

Reclamation Works may be broadly divided into two classes: the one, Inland works, having for their object the reclamation of marshes, the shallower portions of lakes, the tortuous courses of sluggish rivers, or of land subject to flood-overflow; the other, Tidal works, comprising all reclamations effected under tidal influence, whether in estuaries, deltas, or on the sea-coast. In both cases the return

Inland works.

Tidal works.

offered to capitalists generally consists of all or part of the land to be reclaimed, and concessions are granted or money borrowed on terms having such arrangement as a basis. In works of both descriptions drainage is an important feature. While works of this class are those that may appear the most easy to the uninitiated on account of the simplicity of the means and mode of construction usually adopted, yet, in fact, they require the exercise of considerable engineering skill. In those in which the control of river flood is the principal object, an examination of the entire *régime* of the river, from the upland districts down to its debouchement into the sea, and perhaps even the regulation of its whole course, may be necessary,—a matter which requires considerable hydrological study. Even if the enclosure of a certain amount of land in an estuary be the sole object, the navigation of the channel to which the river will be confined, as well as the general effects on the river and on the tidal action, become a matter requiring both consideration and experience; for any evils resulting from imprudent interference with the river's course are liable to perpetuate themselves and multiply to a serious extent. In the very simple case of the shortening the course of an overflowing river, with the object of reclaiming the land on its banks or the area occupied by its former winding channel, although no special skill may appear necessary, yet such works have often been effected in a manner involving damage to riparian interests lower down.

Drainage.

River regulation.

Among the tidal reclamations effected in England, those at Romney Marsh, Morecambe Bay, the Fens in the Eastern Counties, on the rivers Dee, Humber, Forth, Tees, and Tay may be quoted as examples; and among those of the lake class, that of Lough Foyle, of Lough Swilly, and some of the Swiss lakes. The experience these works afford points to the conclusion that simply reclamation works on a large scale are seldom remunerative to investors other than those locally interested, unless the land is so situated as to possess some special secondary advantages. Such advantages are those resulting from a combination with the reclamation of harbour or dock works, river-improvement, sewage utilisation and irrigation, or railway communication; or from bringing into use existing embankments or canals; or from utilising refuse material, such as that of quarries; or from some other circumstances that either diminish the cost of the reclamation works or specially enhance the value of the land reclaimed. To the value of the land actually reclaimed must be added in many instances the enhanced value given to the adjoining land in consequence.

Examples of tidal works.

Of lake works.

Indirect advantages.

Large schemes need Government aid.

The larger the works, the greater is the time required for the development of results; hence gigantic schemes of this nature can only be entertained by investors under specially favourable conditions that include the aid of some Government subsidy or guarantee; such aid being sometimes granted on sanitary grounds for the benefit of the community. There are various ways in which the return to capitalists may be offered, but generally a share in the reclaimed land forms the basis of the arrangement. It is of importance that the promoters of such projects should not only demonstrate the practicability of the works, but should show that they will be remunerative within a reasonable time; that is, either that the land to be recovered will repay with considerable profit all the expenses to be incurred, or that the cost of the necessary works will be reduced by combination with other interests or existing works, or that some local or special considerations will give a higher value to the expected results than that merely of the enhanced worth of the land for agriculture.

Sources of profit.

Demonstration of profit by promoters.

On the other hand, when the reclamation works are of more moderate extent, such as will afford remunerative results within a moderate time, the smaller amount of risk which they involve renders them far more acceptable to the investing capitalist, and, if the calculations be sound, places them in the category of profitable undertakings. Such projects have, however, been frequently laid aside for want of sufficient technical examination. For while many reclamation works have failed because of some rudimentary flaw, others which might have proved successful have been rejected for some invalid objection. For instance, the reclamation of a sandy foreshore has frequently been objected to by scientific persons on the ground that no crops whatever can be grown on pure sand. Undoubtedly the value of reclaimed land depends a good deal on the nature of the soil and its fitness for vegetation, and the alluvial bed of a lake has generally a higher value than a sandy shore; but, on the other hand, sand, when it is to any extent calcareous, forms an excellent sub-soil; it is more easily cleansed from saline matter than either clay or sandy loams, and it is more easily worked in the operations of drainage and tillage; while if it can, by warping or the application of sewage or useful sediment, be covered with but a comparatively small depth of alluvial matter, it may be easily transformed into useful arable land. In this way the sandy banks of many Indian rivers have been reclaimed, and by after-irrigation

Fallacious objections.

Sandy foreshores objected to.

Adaptation of sandy soil.

cultivated profitably. If non-calcareous, the sand may be advantageously mixed with clay, or clay with it, and the clay is usually not far off.

General rules impossible.

It is obviously impossible to establish general rules in regard to these matters, and every project must be judged by the proportion which the trouble, expenditure, and risk will bear to the estimated results. In bringing forward projects of this class for the advice of a qualified engineer and for the consideration of capitalists, the opinion of an experienced land-surveyor and a practical farmer may be taken with advantage. It is always advisable to include in the information furnished to them the accompanying objections, rather than to allow the objections to be raised afterwards, and perhaps magnified by persons not sufficiently acquainted with such matters, or who may be interested in opposing the scheme.

Difficulties should be avowed by promoters.

Protective works.

Protective works are frequently classed with those of land reclamation; they are, however, generally of much smaller scope and extent, having for their less pretentious object the prevention of further aggression on the land by the wasting action of streams and rivers, or of the damage caused by the sea; though sometimes they have the further object of recovering land that has very recently suffered injury from such action. It frequently happens that such works form an important part of a general scheme of reclamation; in which case it is advisable that their expected results be dealt with separately, as far as regards the economy of the undertaking.

Uncertain results.

The uncertain and apparently capricious results which follow the execution of protective works have been exemplified in cases where expensive dams having failed to divert the course of a river, a few judiciously-applied spurs or piles and loaded faggots have answered the purpose; or, on the other hand, in cases where groynes have been constructed with the object of resisting the action of sea waves on a coast, it has been found that nothing less than continuous lines of piling or connected embankments or sea walls could prove successful. These questions depend mainly on the action of currents, and it must be remembered that it is not the usual or average action that has to be dealt with, but exceptional occurrencies from storms or floods. Great care is in many cases necessary to avoid reducing the tidal capacity of navigable rivers.

Interference with rivers, risks of.

Maintenance, danger of neglect.

The maintenance of reclamation or protective works requires perpetual care, any neglect or delay leading frequently to a heavy expenditure. For example, the aggressive action of water on land recently reclaimed, may often at an early stage be combated at a few detached points by such simple means as the throwing in of broken stone, by a few stakes, the planting of saplings, or by turfing the banks; while at a later date a continuous protective bank set back from the water might become absolutely necessary to prevent further encroachment.

Preliminary information.

In order to arrive at any trustworthy or useful decision with regard to reclamation projects, personal examination by an engineer is absolutely necessary. Much valuable preliminary information may, however, be collected and drawn up by local promoters of such undertakings, which may enable the engineer to judge of their merits in the first instance, and to decide whether the case is one worthy of a complete investigation. Such information is indicated in the following list, and comprises the general and local conditions; the more precise particulars which may serve as the basis for the design and estimate of the engineering works; and, finally, those of an economical nature, which may allow the value of the results, and the time in which they are likely to be realised, to be estimated.

Information classified.

Plan and levels.

1. A plan of the area to be reclaimed, with a sufficient number of levels and soundings taken over it, referring to a given datum. The names of owners and occupiers should be marked on the plan.

Catchment area.

2. A map of the surrounding district, including the whole of the catchment area of the river or lake (if the reclamation is of that class) under consideration, or, at least, the portion under tidal influence.

Sections.

3. Longitudinal and cross sections of the area to be reclaimed, or a series of soundings at various points, showing the water-level at different stages of flood or tide, the latter being explained by tables showing the periodical spring and neap tides. Samples of water should also be taken at different depths under varying conditions of flood.

Samples of water.

Sources of supply.

4. The sources of supply of inland waters, if any; their extent, volume, and periodicity; the modes that can be adopted for diverting them and for utilising them.

Climate, rainfall.

5. The conditions of climate, rainfall, and flood; their duration, extent, and effects; with any records of past physical alterations or changes.

Alluvial deposits.

6. In works in which warping constitutes an important item, information as to the amount and quality of the alluvial matter

deposited by the waters, and its rate of deposit under varying conditions of stagnation and velocity.

Pumping. 7. In works in which pumping operations are likely to be considerable, data of the amount of water to be removed, which will serve as a guide to the kind and amount of machinery required.

Existing rights. 8. The extent to which navigation, or other interests, such as foreshore rights, right of watering cattle, irrigation, fishing-rights, water-mills or factories, may be affected by the proposed scheme.

See pages 70 and 158. 9. Information concerning materials, transport, and labour, such as has been already described.

Risks of climate. 10. Exceptional occurrences or freaks of nature to which the locality may be liable, such as excessively high tides and floods, alterations in the course of rivers, hurricanes, or earthquakes.

Condition of soil. 11. The actual constituents of the soil and sub-soil, as ascertained by digging or boring, accompanied by samples and chemical analyses of the land to be reclaimed, and of that in the neighbourhood, in its various stages of fitness for pasture, arable, or other purposes.

Estimate of after operations. 12. Data of the expenditure of time and money likely to be incurred in operations succeeding the simple reclamation and permanent enclosure of the land, such as the drainage, fresh-water irrigation in the case of salt marshes, manuring and improvement of the soil, trenching or other adaptation of the surface, or of any other operations necessary before the land becomes permanently fit for tillage or other intended purposes.

Tenure of land. 13. The proprietary rights in the land to be reclaimed, the tenure under which it will be held by those who are to till it; the value of land of various descriptions in the neighbourhood, and the selling **Value of crops.** price of crops; the distance from the markets; the means of communication in the district, and other data which may form a basis for estimating the value of the reclaimed land.

Collateral profits 14. The probable collateral profits that may be obtained, and the extent to which assistance is directly or indirectly afforded by existing works or arrangements of any sort.

Capital. 15. The mode in which it is proposed to raise the capital, and to apply the anticipated profits.

[*See also* CONCESSIONS: WATER-WORKS: TOWN DRAINAGE; *and in* PART II., PUMPING-ENGINES: PIPES: DREDGERS.]

CHAPTER IX.

WATER-WORKS.

Water-works first among Public Works.

THE supply of Water stands first in order of importance amongst Municipal Public Works. It is impossible to lay down any rule as to the price which a town or district will pay for one of the first necessaries of life, since it is by the need that exists, and by the difficulties of satisfying it, rather than by any fixed standard of value, that the price is determined. It may be assumed that the inhabitants of every town have some existing means of supply; but where regular water-works are not established, their construction will in almost all cases prove beneficial, and will afford a remunerative return for the capital invested. Some or all of the following advantages are generally obtained:—

Water-works generally remunerative.

Advantages afforded.

1. An Increase in the Quantity of water.
2. An Improvement in the Quality.
3. Greater Regularity in the Supply.
4. A Reduction in the Price of water, or in the labour of obtaining it.

Secondary advantages.

It is hardly necessary to enumerate the other advantages, scarcely less important, which spring from these, such as the aid afforded to sanitary measures by the cleansing and watering of the streets, and the flushing of drains; the erection of public fountains; the watering of gardens; the aid to manufactures; and the extinction of fires. Time and trouble are saved to the inhabitants; house property acquires an increased value; and the district becomes generally a more desirable place of residence.

The establishment of water-works tends so greatly to the welfare of a town or district, that it is the duty of the municipality, or other representative authority, to take the necessary steps to promote them. In many English and foreign towns it has been considered

Water-works owned and managed by the Municipality.

Objections to Municipal management.

to the advantage of the inhabitants that the water-works should be constructed for the town or district, and not for a private company, so that the entire control shall remain with those who are most interested, and any profit which may be gained shall be devoted to public purposes. Moreover, a municipality has certain advantages in regard to the acquisition of land, rights of way, laying of pipes in the streets, and enforcing of bye-laws, which it is not always expedient to confer on a private company. While in principle such an arrangement is desirable—and there are many cases where water-works are so conducted to the profit and advantage of the inhabitants—a municipality, whose members are not directly and personally interested in the pecuniary results, is not always so fitted for managing an enterprise economically as are private proprietors whose personal interests are at stake. Often in municipal bodies those who have the direction are too numerous, and have been elected for qualities other than those which would render them able managers. Changes in the management arising from party conflicts, or otherwise, hamper the carrying out of well-arranged plans; and in some cases, even where there is no direct corruption, misapplied patronage will put the direction of affairs into incapable hands. But although in the majority of cases the establishment of water-works is still left to private enterprise, the proportion of such undertakings in the hands of the municipalities tends to increase.

Cost of water-works, how defrayed.

See page 98.

Suitable for local capitalists.

See page 21.

The cost of establishing water-works may be borne in various ways. Where the works are undertaken by the municipality, funds can (in England) be borrowed on the security of the rates either from private investors or from the Public Works Loan Commissioners. If the works are to be undertaken by or for a private company, the enterprise is one peculiarly suited for support by local capitalists. None are so well able to judge of the need as those who share in it, and the undertaking is one of which the utility, even if not the means of performing it, is apparent. The parts of the enterprise which to local investors may be uncertain, *i.e.* the preparation of the scheme and the construction of the works, can be undertaken by others; for, by the employment of qualified engineers, the exact nature of the works which are necessary to produce certain desired results, may be ascertained; and able contractors will be found, to whom payment need only be made as the work progresses to the satisfaction of the engineer.

Preparation of scheme.

Whoever may initiate the undertaking, it is necessary, as one of the first steps, that a feasible scheme shall be prepared and its cost ascertained; and for these purposes an engineer must be employed. The water supply of towns is a special branch of practice amongst engineers, and by the employment of such specialists the experience gained in previous similar works is rendered available. It may be that the source of supply is so obvious, and the necessary works are so simple, as to require no such special engineering skill; and in that case a local engineer, even without peculiar experience in such matters, can prepare the plans which will serve as a basis for an estimate of cost. But if the expense of bringing an experienced engineer from a distance be thus avoided, it is desirable in all but the simplest cases that the scheme be submitted to his inspection afterwards for approval or amendment. The information described on pages 178 to 180—so far as it applies to the case in question—should then accompany the plans, so that the engineer who is consulted may have the necessary material on which to base his opinion. This opinion having been obtained, those who are interested can judge for themselves whether to proceed further with the enterprise.

Specialist engineers.

Having ascertained that the cost of the necessary works is within their means, the promoters may then prudently seek to elaborate their scheme. The engineer may possibly have laid before them alternative plans, each having certain advantages of economy or fitness, and having reached this stage, the promoters, if they determine to proceed further, will generally find that the stronger position they have attained, and the means they have acquired of discussing the next step in the affair, amply repay the preliminary expenses they have incurred. Under the guidance of the engineer, and on the basis of the plans and specifications he furnishes, the promoters may then obtain from capable contractors absolute tenders for the construction of the works. The important question of payment next arises. If the promoters intend to pay for the works with their own money, and to reap their own profit, either from the anticipated revenue or by selling the works to a company, they will have to arrange with the authorities the terms of the concession to themselves. The promoters will then have to satisfy the contractors that the payments will be made in due course, and the contractors, if not satisfied by the mere engagements of their employers, will require security by the deposit of funds in neutral hands, by the guarantee of bankers or merchants, or in some other way. As the

Alternative schemes.

Tenders from contractors.

Payment to contractors.

payments will depend on the certificate of the engineer, the contractors will probably secure themselves on this point also, in the manner already suggested.

See page 23.

Joint-stock company.

If the capital is to be provided, and the undertaking carried through, by means of a joint-stock company, a prospectus may be issued, and subscriptions invited on the preliminary report of the engineer before tenders are obtained; or if it be thought desirable to inspire more confidence in the sufficiency of the proposed capital than the report of the engineer affords, the company can be formed on the basis of an absolute tender from a competent contractor. This latter course is often adopted where the contractor is himself one of the promoters, or is willing to provide part of the capital, and it is then made a condition in the articles of association that the contract shall be made with him.

English usage often unsuitable abroad.

But often in foreign countries the circumstances do not allow the formation of a company in the ordinary English sense, and the promoters, unable or unwilling to pay for the works with their own money, may wish to do so with money obtained from the municipality. Here, again, occurs a fit opportunity for the local capitalists. English contractors or capitalists cannot, except in the case of large and well-known cities with undoubted financial reputation, be expected, without special guarantees, to give credit to foreign municipalities or other corporate bodies. But the credit of such bodies may stand so well in their own neighbourhood that local capitalists will readily trust their promises of payment, if the conditions are only such as they can understand or can transfer to the contractors. For instance, the municipality may offer to pay a specific sum for the water-works directly they are in operation, or in certain instalments during progress; and although contractors as a rule avoid responsibility for the proper designing of works, and stipulate for payment when they have executed work as designed by others, there are capitalists, who for the purpose may be called contractors, who will incur the risk of such engagements, satisfying themselves, either through their own judgment, or by belief in the ability or reputation of the engineer who advises them, that the works designed will produce the desired results.

Municipal credit.

See page 30.

Capitalist contractors.

See pages 38—40.

Payment by bonds.

But the municipality may be unable or unwilling to pay directly in money for the works, and may be able only to offer interest-bearing bonds, payable at some future date. Here, again, the outside capitalist or contractor cannot be expected to value such securities so highly as do the inhabitants, who, having faith in their fellow-citizens and in the stability and wealth of their town, may gladly invest in the securities offered. In both these cases, then—that of payment by the municipality in money, and payment by them in bonds—there arises a legitimate source of profit to the local capitalists or promoters, who, by employing their money or credit during the period of construction, so as to guarantee the payments to the contractor whom they employ, may get the works executed for ready-money payments at a less price than is paid to themselves by the municipality. Sometimes it is desirable or necessary that the contractors shall make their bargain directly with the municipality, who, in the interests of the inhabitants, consider this course the best. If, under this arrangement, the contractors agree to accept the bonds of the municipality, they may still make a bargain with the local capitalists to take them off their hands, at a fixed price, as they are issued. A contractor will assent to such terms if he be assured of three things—first, that no obstruction be put in the way of his carrying on the works; secondly, that the bonds will be forthcoming at the stipulated times; and, thirdly, that the bonds will be bought from him as promised. For the second, he will probably require that the bonds be deposited beforehand in some trustworthy neutral hands, with instructions to the holder that they be handed to him as the works proceed, on the certificate of the engineer. For the third, he will require that the engagement of the promoters or local capitalists to buy the bonds be endorsed by bankers, or others whose capability to pay is undoubted, and who will agree unconditionally to give money in exchange for the bonds as they are presented.

See pages 29—31; also SUBSIDIES, *page 26.*

Sale of bonds by contractor.

Security, precautions for.

While arrangements of the kind just described may prove profitable to the promoters, capitalists, and contractors who share in them, it is questionable whether such methods are the best in the interests of the town, and whether the credit of the municipality, which makes their guarantee valuable, would not be better applied to the direct borrowing of money, which could be expended for the works in question without the burden of intermediate profits. But, while in English towns the borrowing of money for public purposes, on the security of the rates, is sanctioned by the law, and —as affording perfect safety to the capitalist—can be effected at very low rates of interest, such methods are not so well understood or so safely carried out in foreign countries, where, therefore, the less direct plan of granting concessions or guarantees is adopted.

Guarantees inexpedient.

See page 32.

Concessions or guarantees necessary.

It frequently happens that water-works are wanted in towns where there are no local capitalists able or willing to provide money or credit—where, also, the municipality cannot raise the money—and the outside capitalists or contractors are asked to do everything. It may be assumed that the inhabitants have been awakened to the desirability of an improved water-supply; and the municipality, as representing the inhabitants, is willing to grant, to whoever will satisfy their wants, a concession which leaves a profit or return to be found in the sale of the water. As has been already stated, it is the function of the promoters to prepare a preliminary scheme for the consideration of the capitalists whose aid they invoke, and great care is then necessary to arrange such terms as shall allow a fair profit on the outlay, and at the same time be not too burdensome to the town. The advantages which science and engineering skill afford generally allow ample profit for both sides: the new water-supply proves in every way better than that afforded by previously-existing means—and this at a price which, while cheaper or easier than before, allows sufficient margin of profit to the concessionnaires. Assuming that the municipality is in a position to inspire trust in the engagements they make, it only remains to arrange the terms.

Concessions. *See Chapter II.*

Promoters. *See pages 24, 35, 44, 45.*

A monopoly should be conceded for a specific district, within which no one else is to be permitted to establish works or sell water. The length of time for which the monopoly is granted is an important point for consideration. Water-works require some years for their development, and the term is generally for a period between fifty and one hundred years. Fifty years is the shortest time which will allow the concessionnaires to reap a sufficient return for their outlay, and one hundred years is generally the maximum time for which a municipality will bind themselves and their successors, although concessions in perpetuity are not unknown. It is sometimes arranged that at the end of the term the water-works shall become the property of the town, either without payment or at an agreed price. Which of these conditions is equitable, and the length of time granted, depends upon the other conditions and on the amount of profit which is expected annually during the term. Of course, if the works are to be given up without payment, a sinking-fund must be provided out of the revenue to repay the capital. A concession, in granting privileges, imposes certain obligations in return, such as the construction of substantial works; the maintenance of a sufficient supply at a specified pressure; standards of purity; proper systems of distribution; and the supply of water for municipal purposes.

Monopoly of water supply. *See* Monopolies, *page 27.*

Monopoly for term of years.

Right of pre-emption. *See page 37.*

Sinking fund.

See page 34.

Sale of water.

The sale of water may be effected in various ways. Where there are private wells, or other existing means of supply, the purchase of the water may be optional with the inhabitants, and in such a case the income to be derived from the new works is somewhat speculative. This uncertainty may be met to some extent by the municipality, and perhaps also private persons, agreeing in advance to take a certain quantity of water annually, at a fixed price: a small income may be thus secured, sufficient to induce the concessionnaires to risk the rest. The price at which the water is sold may be arranged in several ways. When large quantities are wanted for public or manufacturing purposes, the water may be measured by meter, and a price per 1,000 gallons, or other unit of measurement, agreed upon; but for ordinary domestic consumption such a plan is neither convenient nor desirable, and fixed annual charges are generally arranged. Although the consumption does not exactly depend on the size of the house, the rental is a convenient basis for the calculation of price; and as, moreover, the rental is usually adopted as a basis for the assessment of taxes, the official valuations already existing for this purpose are available for reference, although they are not, without alteration, always suited for adoption.

Guarantee of revenue.

See page 28.

Measure of price.

Water-rate based on rental.

It may be said generally that where the concessionnaires have the right to charge a rental-rate for water, and where the use of the water is obligatory on all houses—or practically so, by the absence of other good means of supply—the concession, if properly arranged, is of a character to induce capitalists to take it up. Besides the supplies for municipal and domestic purposes, there are generally other sources of revenue. Tariffs of prices may be arranged for extra private supplies: manufactories, baths, gardens, and fountains require water; if at a port, the shipping also; and these afford sometimes considerable profit. A portion of the supply may be used as power for raising water to the higher levels of a town; the water thus utilised forming afterwards, if need be, the supply for the low levels. If the pressure in the mains can be always maintained at or above 40 lbs. per inch, the water is available as power for driving engines, cranes, and machinery, in factories, warehouses, and workshops, and, while thus affording a great convenience to the inhabitants —especially for industrial communities—the company opens out a valuable source of revenue. The transmission of power by water has in some towns been carried to great perfection; and the system, as being profitable to all concerned, is likely to be extended in the

Tariffs of prices for extra supplies.

High-pressure water utilised as power.

See in Part II. TRANSMISSION OF POWER. WATER ENGINES. HYDRAULIC CRANES.

future. The concession may be made also to include a monopoly of all works in connection with the water-supply, such as the laying of new pipes, the connections and fittings in houses or wherever a connection or alteration has to be made in the pipes. A concession with such a monopoly, if a proper scale of prices be agreed upon, may be alike advantageous to the town and profitable to the concessionnaire.

Monopoly of extra work.

Privileges needed by water companies.

In arranging the terms of a concession, it is important to stipulate for certain secondary but necessary privileges, such as the right of way through the streets for extensions; free access, at all times, to the mains in the streets; the right of entry into houses, to inspect or alter pipes, for the prevention of waste or theft of water; the right of erecting new works. The conditions of this sort which may be necessary depend upon the special circumstances of each case, and must be arranged accordingly. Bye-laws are also necessary for protecting the property of a Water Company, and in England the Acts of Parliament authorising water-works undertakings so invariably allow such bye-laws, and provide penalties for their infringement, as to accustom the public to them as part of the ordinary law of the land. In countries where the English usage in such matters is not established, it is very important that the necessary stipulations be included in the terms of the concession, as it may not be easy afterwards to obtain them. Such bye-laws protect a Water Company against the theft, waste, fouling, or misuse of the water; give power to recover rates in arrear, and to stop the supply in case of non-payment; and generally afford that legal protection which is equitable in return for the obligations undertaken by the concessionnaires.

Bye-laws.

Penalties for infringement.

Nature of bye-laws.

Although a municipality may leave the concessionnaires to make their profit from the sale of the water, as just described, and may decline to guarantee permanently either a minimum revenue or interest on capital, an exception may be made for the first few years. The expenses of the first two or three years are not unfrequently large, and the anticipated incomings may be at the beginning so small as to forbid the hope of a nett revenue. The risk of this may be sufficient to deter capitalists from embarking in a scheme which they believe would in a few years' time be sufficiently profitable; and a municipality may find it to their advantage to encourage capitalists to construct their water-works by guaranteeing, for three years, or during the execution of the works, interest on the money invested. Where the capital is to be raised by means of a joint-stock company,

First year's outlay unremunerative.

Temporary guarantees.

such a limited guarantee is of very great assistance in inducing contributions.

Another shape in which assistance may be rendered in cases where the prospects of profit prove insufficient to attract capitalists or contractors, is by the municipality offering a subsidy in money to whoever will bring water to the town. In many cases such a subsidy is in the shape of a bonus or free gift, and the capitalists are still left at liberty to retain all the profit they can make from the works. But very often in return for the subsidy, the obligations of the concessionnaire are made more onerous; and both subsidies and guarantees have frequently the inconvenience of allowing too much official interference and control.

Subsidies.

See also page 26.

Official interference.

The systems of water-supply are broadly classed as Gravitation and Pumping systems, and the cost of the works is of course primarily determined by the circumstances of each case, which render one or other system necessary, and by the extent and solidity of the works. A lake or source of supply situated on an elevation near a town, and affording always a constant supply of pure water, is a favourable instance of a gravitation scheme, and such a project is obviously much cheaper than one where the water has to be pumped and stored and filtered. It is, however, a mistake to suppose that gravitation schemes are necessarily the cheaper, and if an average could be arrived at, it is even probable that the cost, whether compared according to the quantity of water supplied, or per head of population, would be found to be greater than for pumping. In gravitation schemes the expenditure incurred for impounding-reservoirs for storing against dry seasons, and for the bringing of water long distances, is often so great as to exceed not only the cost of machinery necessary in pumping schemes, but even that of the annual expenditure for pumping, if the latter be capitalised so as to afford a fair comparison with the capital expenditure in a gravitation scheme where no pumping may be required.

Systems of water supply.

Gravitation *versus* pumping.

Expenditure compared.

Whatever be the original level of the source, it is in almost all cases considered best to bring the water into high-level reservoirs, from which it may flow downwards in its course to and through the town. The height of the reservoir determines several other points of importance. As water flows to its own level (subject to a slight loss by friction in the pipes and by leakage), a high reservoir will afford pressure sufficient to force the water wherever pipes are laid

High-level reservoirs.

High-pressure water for fire extinction.

to an almost corresponding height in the town. Not only is this a convenience to the inhabitants, but it is of very great value in the case of fire, as the high pressure in the mains in the streets affords a supply, which (subject to certain qualifications) can be discharged at any point through a hose-pipe without the necessity for fire-engines. Where the supply of water is very abundant it may, as already stated, even be used as a motive power for driving machinery.

See FIRE-ENGINES *in Part II.*

Zones of different altitude.

A pressure of more than 200 feet is generally found inconvenient for domestic supply, as the necessary fittings become costly and there is great loss by leakage, Where, therefore, the supply is at a greater elevation, the service reservoir is placed at a lower level; and if the town be situated on the slope, it may be divided into zones of different altitude, each zone having its own service reservoir.

Low-pressure supply.

Supply confined to street tanks or fountains.

Where the source of supply is not at a high level, or where there are no elevated positions available for reservoirs, or where for these or other reasons the cost of obtaining high-pressure water is greater than can be afforded, it may be sufficient to bring the water into the town at a low pressure. In some cases pipes are not taken along all the streets, but merely conduct the water to local reservoirs, tanks, or fountains, from which the inhabitants can fetch their own supplies. This system, though seldom adopted in English towns, and though obviously incomplete, may be adopted where a cheap first cost is important, or where it accords with the habits of the people, leaving for future consideration or for private enterprise the greater conveniences of water inside the houses.

Quantity of water, how determined.

Consumption of water in English towns.

Allowance for waste.

Supply for trade and municipal use.

The quantity of water required for a certain population depends upon climate, upon the habits and occupations of the people, on the mode of distribution, and on the waste. In England the actual quantity required for domestic purposes varies from ten gallons per head per day in small houses, to twenty gallons in large houses, and an average of fifteen gallons may be reckoned on as sufficient. But these quantities, while adequate even for towns where there is a constant service—that is to say, a supply always available in every house, by simply opening a tap placed in direct communication with the water-main, and not, as in many parts of London, a certain quantity discharged into a cistern once a day—do not include any but a moderate allowance for waste, and it is obvious that there is no limit to the latter under careless or incompetent management. For municipal and trade purposes, from seven to ten gallons per head per day is generally found sufficient, although this amount may be exceeded where there is a large demand for particular trades, for fountains, or other public uses. In those English towns where proper rules and regulations in regard to pipes and fittings for the prevention of waste are enforced, the total quantity consumed for all purposes is from fifteen to thirty gallons, while in others, where a wrong system or inefficient management prevails, the quantity ranges from thirty to sixty gallons. Efficient supervision to prevent waste costs less than additional interest on the increased capital expenditure which a large supply to cover waste will require; and if the latter system be adopted, a remunerative return to the investors can only be obtained by the imposition of high and burdensome water-rates. Where it is difficult or expensive to obtain pure water in sufficient quantity for the total consumption, two distinct services may be provided: one line of main pipes being charged at high pressure (from 100 to 200 lbs., according to the height of the houses) with pure water for potable and culinary purposes, and for fire extinction; and a separate service of unfiltered water for less important domestic use, for street watering, and other secondary purposes. If the latter service is also maintained at high pressure, it may be used for fire extinction, to the saving of the potable water. In view of the growing scarcity of pure water in the vicinity of large towns, it is probable that some such system of dividing the supply as is indicated above will have to be frequently adopted in the future.

Waste prevented.

Separate service for potable water.

In deciding upon the quantity of water to be supplied as the preliminary step for determining the kind and magnitude of the works, it is expedient to provide for a growth of population and an increased demand. In England, an allowance of from twenty-five to fifty per cent. beyond immediate wants is generally considered a prudent margin; but of course this question must in each particular case be largely decided by the probabilities of an increased population, on the extra cost involved in providing for it, and on the funds available. Moreover, in considering the question of cost, the trouble and expense which would be incurred in the future, if works only for the present demand were constructed, must be compared with the cost of doing all at the beginning. Such a comparison will vary according to the nature of the works. Thus in a gravitation scheme, with impounding or storage reservoirs, and long lines of aqueduct, it will almost always prove more expensive to enlarge or duplicate such works in the future than to make them in the first instance sufficient for a growing population; while if the water be obtained

Growth of population to be provided for.

Future expenses for extensions compared with first outlay.

by pumping, additional engines and even service reservoirs may be added in the future almost as cheaply as in the first instance, if land (and for engines, buildings also) be kept in reserve from the first. The margin of supply-power need not therefore in the latter case be as great as in the former. In either case it should be remembered that money at compound interest soon doubles itself, and capital left unproductive is a great burden on the undertaking. As, however, a stoppage in the supply of water to a town would be disastrous, apparatus—such as engines, boilers, and pumps—subject to accidents in working, or needing periodical repairs, should always be provided in duplicate from the first.

Unproductive capital.

Duplicate apparatus.

Tendency of cost to increase.

The cost of water-supply must obviously vary considerably according to the nature of the works, and in England the tendency has been towards an increase in the cost, caused partly by the difficulty of obtaining new or additional sources of water in the vicinity of towns, and partly by the rise in the prices of labour and materials. Where the works have been well designed, and the consumption kept by efficient management down to twenty-five gallons per head per day, it will be found that the capital expenditure varies in all but exceptional cases from £1 to £3 per head of population. A larger cost can be afforded for the gravitation than for the pumping schemes, as the annual expenditure for pumping must be set against the interest on the excess of capital on the former. But in many towns the systems of water-supply have either been ill-considered from the first, or have been enlarged, supplemented, or altered without a fixed plan; or though well designed have had to overcome exceptional difficulties, and in such cases the expenditure reaches even £7 per head. In London and Liverpool the capital invested in the different waterworks is about £4 per head of the population supplied. Where, as is often the case, the high cost has to be borne by the municipality, the inhabitants suffer by having to pay heavy rates, the investing capitalist having a fixed interest secured to him. But where private concessionnaires or water-companies obtain powers to supply a town with water, and agree beforehand to certain rates or tariffs of payment, they and not the inhabitants have to bear the loss if the expenditure prove more than was anticipated. There are, on the other hand, exceptional cases where a heavy expenditure at the first is a wise policy. For instance, in a large colonial city with a rapidly growing population, the most convenient source of supply, though

Outlay in proportion to population.

Causes of heavy outlay.

High water-rates.

Heavy outlay sometimes justified.

far in excess of immediate wants, may require, to render it available or secure, an expenditure proportioned to the potential rather than the immediate benefits it affords.

Working expenses.

Rental rate.

Average rate in English towns.

Sale of water by meter.

Tariff of prices.

Value of water, how determined.

The expense of procuring and distributing water will be found generally to range from 3d. to 9d. per 1,000 gallons, these rates including interest on capital and current expenditure. The rental rate for water charged in English towns ranges from 6d. to 1s. 6d. in the £ (in London it averages 12d.); but as the value of houses depends on many varying conditions which have no relation to the cost of water, these rates do not afford a fair comparison. Where water is sold by meter, there is a wide difference in the rates demanded by different water companies; in some instances a price as low as 4d. per 1,000 gallons being charged, and in some as high as 2s., but in almost all cases large consumers—railway companies, manufacturers, and others—are charged at a sliding-scale price, the rate being in inverse ratio to the quantity consumed. The cost and value of the water depend upon whether it has been purified for drinking or is only fit for inferior purposes; upon the degrees of hardness by which its fitness for washing and various manufacturing purposes is determined; and on the pressure which may or may not take it to the top of a building or render it serviceable for driving machinery.

Interest paid by water companies.

In Great Britain, the average dividend paid by water-companies to their shareholders is about seven per cent.; but it is to the monopoly they enjoy rather than to any peculiar skill in administration that their prosperity is due.

Cost of foreign water-works.

In calculating the cost of water-works in new or foreign countries, although sources of water may be more easily accessible than in England, land more plentiful, and rights of way more easily obtained, there are frequently, on the other hand, expenses not incurred in England, of long carriage on pipes and machinery, import-dues, and scarcity of suitable building materials.

Information necessary for a scheme.

The following is the information which is necessary as a basis for designing water-works and for calculating their cost. To the various particulars here described, an engineer on the spot would direct his attention, and the same information will aid engineers who have not seen the locality in suggesting the best methods and the probable expense, leaving the exact details perhaps for verification and final decision afterwards on the spot. As the information described is

Particulars classified. meant for general application and to cover a variety of cases, it is obvious that in every instance some of the particulars may be omitted and possibly others added.

Map. 1. A map of the town and adjoining country, showing the positions of the wells, springs, rivers, or lakes, from which water may be obtained. Where there is a question as to the sufficiency of the water which certain streams can afford, a correct estimate can only be based on a knowledge of the extent of the catchment area of the rivers; the rainfall; the amount lost by evaporation; and the absorbtion as determined by the geological formation. Neighbouring elevations, natural basins, and other sites suitable for reservoirs or filter-beds, should be indicated; and the levels of the different sources should be given, as compared with some fixed datum in the town. **Catchment area of rivers.**

Geology of watershed. 2. As accurately as the circumstances will permit, the geology of the watersheds or of the sites of wells; and wherever works are proposed, trial holes or borings should be made. A description of each of the sources of supply which are available for consideration, giving as nearly as possible the nature, quality, and amount of the water; the levels of water in the wells of the locality, the strata through which the wells penetrate, the quantity of water obtained from them, and how far, if at all, the supply is liable to be affected by mining operations or by contamination from surface drainage.

Flood levels. 3. If the sources from which the water is to be taken are periodically or occasionally flooded, trustworthy information as to the levels should be furnished, and the effect produced by the floods on the quality of the water described. If possible, the maximum quantity of flood-water per minute should be stated; also the dry seasons, if any, which produce scarcity of water should be described, in order that, if necessary, the scheme may include provision for the sufficient storage of water. A knowledge of the alterations in the levels of the sources is also necessary to determine the works at the in-take of the water; and in giving information on all these points, the experience of as many past years as possible should be furnished, so as to include exceptional as well as ordinary seasons. **Dry seasons.**

Right of water. 4. The right to take the water should be affirmed, and if in taking the water, existing rights of mill-owners or others below the point of abstraction are interfered with, the circumstances should be described, and the terms which may be arranged. In connection with this, the number and value of mills interfered with should be stated; also whether the water is in such mills used for power or for manufacturing purposes; and if for power, the size of the wheels and the available fall. Any other public works, undertakings, or circumstances, in the neighbourhood of the town or of the water-sources, which may in the future be likely to affect the supplies, should be described.

Interference with vested interests.

5. Samples of the water should be furnished for analysis, and the times and circumstances in which the samples were obtained carefully described. The samples should be transmitted in perfectly clear glass bottles, containing, if possible, not less than a gallon, well stoppered and sealed (not corked), and these samples should be accompanied by any analysis which may have been made on the spot.

Samples of water.

6. A description of the existing water supply, showing the quality and abundance of the water at different seasons, and its cost to the inhabitants.

Existing water-supply.

7. If it is proposed to take the supply from a river affording power for working pumps, such particulars should be furnished concerning the fall available, the velocity of the current, and quantity of water per minute at different seasons, as will enable the engineer to consider the expediency of using water-wheels or turbines for raising the water, and for deciding upon the kind and size of such machines.

Water-power for pumping.

8. A plan of the town on a sufficiently large scale, showing the principal thoroughfares through which the main pipes should be laid, the side streets in which pipes will be wanted, the position of public buildings or manufactories requiring large supplies of water, the sites for fountains, or wherever else water will be specially required. The levels of all these places should be given.

Street plan.

9. Local information of the kind described in a previous chapter, with regard to the landing and transport of materials, import duties, cost of building materials and labour, and especially with reference to the following points: The kind of gravel or sand obtainable as suited for filter-beds; of sand for mortar, cement, or concrete; clay for puddling; and clay, lime, hydraulic-lime, bricks, stone, slate, and timber, suitable as building materials; iron pipes, blue lead for pipe jointing; coal or other fuel for pumping-engines, and the cost of such materials; a description of the kind of labourers and different kinds of skilled workmen, and the rates of wages.

Materials and labour.

See page 70.

10. The climate should be described, not only as regards the points enumerated for railways, but with respect to the following:

Climate.

See also page 70.

Rainfall. The rainfall for each month for as long a series of years back as possible, and how it has been ascertained; the evaporation, and how ascertained; Frost. the degrees and continuation of frost, and the depth to which it enters the ground; the thickness of ice on the rivers, and how often it occurs; the temperature, maximum and minimum, of the water to be used.

Site for pumping station. 11. If a site has been selected as suitable for a pumping station, the nature of the foundations for building should be described, and it should be stated if water other than that to be obtained for supplying the town is available for condensing the steam in the engine. No very pure quality is necessary for this, and surface-water may be used, or the condensed steam and water stored and re-used.

Stratum in pipe trenches. 12. The kind of road material along the lines of pipes and the subsoil in which trenches will have to be cut. As water pipes should not be placed in close contiguity to gas pipes, the position of the latter should be shown on the plan.

Tenure of land. 13. The conditions upon which land can be obtained, the authority under which it may be taken, the tenure upon which it may be held, its value, and the cost of the process.

Population. 14. The population of the town and district which is to be served with water, the rate of increase in the population during preceding years, and the probability for the future.

Number and kind of houses. 15. The number of houses and tenements, and the rentals per annum, divided into classes, advancing by steps of about £10 The general height of the houses, and the maximum height.

Wealth and occupations of the people. 16. Some information should be afforded as to the wealth and occupations of the people, so far as will aid in estimating the amount of water required and the means of paying for it. Information under this head should tell whether the inhabitants wash linen at home; Nature of drainage. *See* CHAP. X. whether baths are usual in the houses; the manner in which the houses and streets are drained; and whether any complete system of drainage is established in the town, or is in contemplation.

Description of project. 17. If a scheme of water-supply has been already prepared, a description of it should be furnished, showing the proposed methods of raising money, the terms of concession offered by the municipality, and the calculations of cost, revenue, and profit.

[*See also* CONCESSIONS: IRRIGATION: TOWN DRAINAGE; *and in* PART II., TRANSMISSION OF POWER: PUMPING-ENGINES: PIPES: FIRE-ENGINES: WATER-ENGINES: HYDRAULIC CRANES.]

CHAPTER X.

TOWN DRAINAGE.

ESSENTIAL as good drainage works are to the comfort and health of a community, they are seldom undertaken until the necessity is forced very strongly upon those concerned. Even in Great Britain, where civilisation might be thought sufficiently advanced to ensure a proper appreciation of such advantages, municipal authorities have always been backward in adopting improved methods of drainage; and this mainly because the expenses of new schemes are more apparent than the promised benefits. Old systems of drainage, or rude methods of removing sewage, are considered sufficient by those who are accustomed to them, and even persons of education cannot, or will not, in many cases, be brought to see how much the health of a town may be improved and its mortality diminished by proper drainage works. Although the scientific evidence on such matters is ample, and is confirmed by the statistics of the health of towns, the inhabitants and ratepayers, through the representatives whom they elect, will too frequently by passive or active resistance postpone as long as possible the necessary sanitary works; nor will the occurrence of epidemics always prove sufficient to rouse them. In England it is only since Parliament by legislative enactments has brought a superior power to bear upon all urban authorities, that those who were unwilling or unmindful have been forced to take the necessary action. If such has been the case so often in Great Britain, similar negligence in foreign cities, where public opinion is not so educated, is not astonishing.

Necessity for drainage works.

Town authorities backward.

Opposition to sanitary works.

Town drainage enforced by Parliament.

In countries where the inhabitants are of inferior race, or of uncleanly habits, or where there are established defects in drainage, and especially in countries where the climate intensifies the dangers of neglect, the necessity for drainage works is even stronger than in England, and the results which such works afford proportionately

Dangers of neglect intensified by climate.

greater. The advantages obtained are not to be measured only by the low average of mortality, but also by the diminution of sickness, and by the comfort and decency in daily life afforded to all classes of the community.

Expenses of drainage, how defrayed.

Money raised by lotteries.

Octroi duties.

Evils of octroi duties.

Restraint of trade.

See also, page 1, FREE TRADE; *and* MARKETS, *Chap. XIII.*

Octroi duties in India.

Octroi or town dues in England.

Coal and wine dues of London.

The money necessary for town-drainage, street-cleansing, and similar sanitary works, is generally raised by local taxation, and only occasionally—as sometimes in the case of capital cities—do national funds contribute. In some countries advantage is taken of the love of gambling to raise money by lotteries, in which, while there are great prizes, a considerable proportion of the subscribed money is retained by the authorities, or paid in commission to agents. More often in foreign cities the expenses are defrayed by indirect municipal taxes, levied in the shape of *octroi* duty on goods or provisions entering the city, and the inhabitants in most such cases would resent the imposition of the more economical, though apparently more oppressive, direct taxation. It is questionable whether *octroi* duties, though less demoralising than lotteries, are not as wasteful. For such duties require the employment of numerous officials; involve smuggling, with its attendant evils; and cause an enhancement of price to the retail purchaser equivalent not merely to the tax, but also to the profit on the tax which each trader, through whose hands the commodities pass, puts upon his outlay. To these immediate evils are added the restraint of trade which interference always involves, an *octroi* duty often being in effect a transit tax on goods merely passing through the town: for, though systems of drawbacks or refunding are generally established, the regulations are vexatious enough to turn the scale in favour of a town not so hampered, in the competition of traders to make the market an entrepôt or centre of commerce. In British India, where among the smaller municipalities the ancient system of *octroi* taxes is still maintained, the Government is only able gradually to introduce a sounder system. In England, *octroi* taxation is almost unknown, except in the case of port or harbour dues, which are in some English towns applied to municipal purposes. These dues are very often authorised by ancient charters, and are most frequently levied on coal or corn, and in some cases have been merged into duties on such commodities whether sea-borne or land-carried. In this way the coal and wine dues of London have been perpetuated, and the 1s. per ton levied on all coal entering the metropolitan district (embracing an irregular area of about 12 miles' radius from the city) has been applied to sanitary improvements. Although the extinction of the tax is decreed, it is for many years to come pledged for payment of the interest and principal of loans.

Urban sanitary authorities.

In Great Britain, the Urban Sanitary authorities of each town (generally the Corporation, or, in unincorporate towns, the Local Boards of Health established for the purpose), are empowered by law to borrow money on the credit of the rates for capital expenditure on new works; and loans on the security thus afforded are sometimes granted from the public funds; it being a condition of such borrowing powers that a sinking-fund shall be provided, so that annually not only the interest, but also a part repayment of the capital shall be borne by the revenue of the current year. Money is also advanced by Life Assurance Societies, who have to find employment for their large reserve funds, and who—unlike bankers—do not require a speedy return of the money lent, although they generally stipulate that the loan shall be repaid by annual instalments in a prescribed number of years. Although in the majority of cases such financial arrangements have proved successful, the question has been raised, and will probably receive considerable attention, whether the system is in English towns equitable. As the taxation falls exclusively on householders, and as many of the houses in English towns are held on short leases, the freeholder, on the expiration of the period of the loan, reaps all the advantage of the improvements to which he may not have contributed anything.

Borrowing powers.

See also on page 98, LOAN COMMISSIONERS.

Sinking-fund.

Loans from Life Assurance Societies.

See BANKERS, *page 41; and* SYNDICATES, *page 42.*

English system unfair to householders.

Drainage works of London.

See page 194.

The drainage works of London are for purposes of construction and management divided into two distinct classes, the main drainage and the local sewers. The main drainage has been undertaken by the Metropolitan Board of Works, a constituent body formed for the purpose, although it performs many other functions. Most of the money for the large arterial sewers, reservoirs, and pumping stations which compose the main drainage system has been raised by loan as just described, and the security is considered so good that as much money as is required is easily obtained at a rate of interest of 3½ per cent. per annum. The taxation for paying the interest and repaying the principal of the loans (except those raised on the special security of the coal dues) is levied as a rental rate over the whole metropolitan area which is benefited; but the duty of collection is entrusted to the authorities of each separate parish or district, who are called upon twice a year to contribute the quota which is due from them. It is

Metropolitan Board of Works.

Rate of interest for loans.

See LOANS, *page 30.*

Rates, how levied.

endeavoured by periodical assessments of value to make the burden lie equally, so that a similar rental rate on all districts may represent a real similarity in taxation. The local sewers of the metropolis are constructed by the authorities of each parish, or group of parishes (called districts), from funds raised in a similar way; the duty of the local authority ending when the sewage reaches one of the main arterial sewers. The street-cleansing and general sanitary works are also managed and paid for by each district separately. The plurality of authorities who thus direct the municipal affairs of London is often a cause of great inconvenience: there is a want of uniformity in the management; the expenditure is unduly great; and reforms or improvements much needed are rendered almost impossible.

Local sewers of London.

Divided authority in London.

Most provincial towns in England are able to borrow money at rates varying from 3½ to 5 per cent. per annum, there being various secondary reasons which in the minds of investors render such loans worth a slightly higher rate of interest than the metropolitan loans: the latter, being of larger amount, are more widely distributed and are better known; the growing value of the security is more apparent; trust funds may be legally invested in the stock; the interest is paid quarterly; and transfers can be effected in the metropolis. For these reasons the stock can at any time be easily disposed of—a point always regarded by investors as important, apart altogether from questions of security.

Provincial loans.

Metropolitan loans preferred by investors.

Reasons for preference.

See also pages 30 & 41.

The English system of providing funds is adopted in many of the colonies, but as local capital is not so easily obtainable at moderate rates of interest as in England, outside aid has often to be invited; and in the case of large towns, municipal loans are issued by the permission of the Colonial Parliaments, and are generally well regarded by English investors.

Colonial loans.

See also page 14.

The terms upon which capitalists and contractors will carry out foreign projects have been already referred to. But conditions applicable to the special nature of drainage works are of course necessary, for there is the marked difference between drainage works and such undertakings as railways and waterworks, that the former, in not being directly remunerative, lack the collateral security which the earnings of the latter afford. If, therefore, local funds are not forthcoming, outside capitalists will be more than usually cautious in satisfying themselves of the sufficiency of the security

See Chap III.

Contracts for foreign drainage works.

See page 39.

offered. Sometimes, as in England, the municipality raises the funds directly by loan, pledges its credit unconditionally for payment of interest and capital, and then makes a separate bargain with the contractor for the works. In such cases, where secure money payments are to be depended on, contractors or promoters can expect a preference only where they afford assistance in other ways, such as by making the preliminary plans, or by subscribing to the loan. Sometimes, however, the municipality does not raise money directly by loan, but prefers to grant a concession to suitable persons willing to undertake the works. In such cases the contractor may be paid by interest-bearing bonds, which are to be redeemed at some period after the works are completed, the due payment being secured by the ordinary revenue of the town, or by the hypothecation of certain property or taxes. Another mode of payment (adopted at Rio de Janeiro) somewhat resembles that usual for waterworks. Instead of taxing the general community, a special rate is levied upon each house according to its rental. The concessionnaires have the right, when they have conducted the drainage of each house into the sewers, to demand from the municipality annually a certain sum, and have the obligation and right of connecting the drains of new houses as they are built. As, according to this plan, a large outlay must be made before payments become due, contractors with considerable capital are alone able to undertake such works. An additional revenue is sometimes obtained from the town as payment for the ordinary street drainage, and sometimes a subsidy in money is given besides. It only depends upon the terms of such engagements to make them as profitable as those for any other public works. The bargain generally grants to the concessionnaire the property of the sewage as manure; but it has been sufficiently shown that the value of the sewage will not alone compensate for the works and labour of removal; and unless there be unusual facilities for its immediate conveyance to agricultural land, the sewage has to be filtered, deodorised, or otherwise rendered inoffensive by the contractor before it can be made available as manure, or the effluent water be allowed to flow away. All these conditions are obviously matters for special arrangements in each case.

Methods of raising money.

Concession granted. *See Chap. II.*

Payment by bonds. *See pages 26, 30, 169.*

Rio drainage. *See page 202.*

Rental rates for house drainage.

Extra payments.

Subsidies.

Sewage the property of contractor.

See page 201.

In deciding upon the methods of drainage which are best suited to any particular locality, considerations of economy affect the question in various ways. The truth of the proposition that sewage

Methods of drainage.

Sewage should be utilised on land.

should be given to the land is universally acknowledged, and sanitary engineers in all countries would willingly conform to such a law of nature, and not only thus find a means by which they can be rid of the sewage, but at the same time make its disposal a profit instead of an expense.

Differences of opinion.

Differences of opinion amongst engineers on this point have been magnified because of the very different sides from which they approach the question, and from the want of experience or trustworthy *data.* Some, in their earnest desire to utilise the sewage, and in the very sanguine hopes they entertain of success, are apt to risk failure in the primary and more important sanitary task.

Difficulties in utilising sewage. *See page 197.*

The size of large cities, the crowded population, the manner of conveying the sewage, the absence of a regular water supply, the method of purification, the want of suitable land, the difficulties of applying the sewage, and the very low value it possesses (especially when diluted by street drainage) in proportion to its bulk, are obstacles which, singly or together, have up to the present time, in the majority of cases, baffled the ingenuity of those engineers who have sought to make sewage irrigation profitable.

Measures of value for sewage.

There are cases where crude sewage can, with advantage, be put upon the land, and the time will probably come, as other kinds of manure become more expensive, when sewage will have such an increased value as to justify more frequently the cost of so using it. But so long as other manure can be more easily or cheaply obtained,

Wasteful application of sewage.

it would be as wasteful to apply the sewage (unless for sanitary reasons) as to take pains to utilise some waste material for fuel when the equivalent in coal could be purchased at a less price. There is, perhaps, no problem among those which the engineers of the future have to solve which is more important to the welfare of mankind than the economical disposal of sewage, and in no branch of engineering are there such marked differences of opinion; but if it be

Proper systems available.

acknowledged that the sanitary work is a necessary and legitimate cause of expense, experience has already (1877) sufficiently accumulated to show the means—singly or together—by which the desired result can be achieved.

Climate and circumstances vary.

The climate and the local circumstances in most foreign towns differ so widely from those in England, that the systems of drainage and the methods of procedure usual in English towns cannot be applied. In countries subject to alternate dry and rainy seasons the arrangements for street cleansing must necessarily be different from those in England, where periods of more than a few days without rain are rare. An insufficient or irregular water-supply is also a great cause of difficulty, and where no regular water-works exist, their construction either in conjunction with or as preliminary to the drainage works is an essential part of any complete sanitary scheme. The house fittings and sanitary appliances are in most towns not of English origin of an insufficient and backward kind, and the inhabitants have generally standards of comfort and decency which would be unendurable amongst an English-speaking people. Modern travel, and the comparisons—so disadvantageous to themselves—which such intercourse forces upon foreigners, is leading to the introduction of English systems abroad; but the expense which such systems involve, generally forbids their adoption when only increased comfort or decency is the anticipated benefit; and it is the occurrence of epidemics, or a permanently high death-rate, which finally induces the adoption of improved methods.

Insufficient water a difficulty.

Foreign sanitary works backward.

The liquid sewage of a town consists of the surface and subsoil water resulting from the rainfall, which brings with it the street sweepings and other surface impurities; and the sewage from houses, stables, and factories. Where no proper system prevails, the street drainage is generally allowed to flow along open gutters (into which often the house slops are emptied), and thence by ditches outside the town into the nearest river. These open conduits are not only offensive to the sight and smell, but too often also spoil the wells of the locality. The evils of such a system are reduced to a minimum when the gutters are well flushed; and in towns possessing an abundant supply of water, a copious and continuous flow along the street gutters tends to render them innocuous. In the case of towns situated on low-lying or marshy grounds, surface and subsoil drainage is a matter of great importance, quite apart from the more difficult question of house sewage. Although in the great majority of cases where improved systems of drainage are established, the two kinds of sewage are treated together—the rain-water and street gutters helping to flush the drains which convey the house sewage—it is the opinion of some engineers that the two should be kept distinct, so that the house sewage, no longer diluted, shall retain its full value as manure; and in countries subject to heavy rains it is impossible to provide for rain-water in the sewers. The separate system finds its chief justification in those cases where the sewage has to be lifted by pumping (and where, therefore, it is desirable to reduce the bulk and weight), and where the sewage is allowed to flow on to land in a crude condition.

Town sewage.

Improper systems.

Flushing of open conduits.

Sewage kept separate from rain-water.
See page 198.

Disposal of house-sewage. At present, house-sewage is disposed of in various ways. The old-fashioned middens and cesspools are still used in a vast number of towns, and cannot be too strongly condemned. In some cases the **Evils of cesspools.** cesspools are periodically or occasionally emptied, and their contents buried in waste land, or taken to agricultural land for manure, or thrown into the sea; in others, they are never emptied, and when full others are used in their stead. In towns where the means or disposition to construct sewers are wanting, or where the absence of a regular water-supply would render removal in a liquid form difficult, or where the inhabitants, from their ignorance or prejudices, would be likely to neglect or misuse the arrangements necessary to water-carried sewage, then these ruder systems must be made the best of. In most towns a regular organisation exists for the removal of ashes and other house refuse, and by an extension of the same organisation **Dry-earth and pail systems.** to the "dry-earth" and "pail" systems, it is attempted to remove sewage matter from houses in a solid or semi-solid form; but, to render such methods successful and inoffensive, every part of the apparatus must be properly designed, each detail in the operation **Precautions necessary.** suitably arranged, elaborate precautions taken for cleaning and deodorising, and the supervision must be constant and vigilant. **Difficulties.** The difficulties which generally hinder the adoption of these systems are none the less because they are made up of details, for the minor inconveniences of periodically entering private premises, of carrying and carting offensive matters through the streets, and of disposing of them promptly, are—if the English standard of decency and comfort be considered—very great; yet in towns without water supply and closets after the English fashion, such a carefully-organised system of periodical removal may be the best. Such systems, however, find their easiest application in villages or small towns. So **Conditions of success.** much depends on the local circumstances of each case, the size of the place, the situations of the houses and offices, the supply of suitable earth or other deodorants, facilities for removal, contiguity of agricultural or waste land, and other essential conditions, that the plan cannot be recommended for general adoption in large towns. Those who defend the pail and cart method not merely as a substitute under certain circumstances for the water-carried system, but as superior even where there are available sewers and abundant water, are apt to overstate the disadvantages of the latter; but the anticipated evils need not arise if proper attention is paid to ventilation, and if there are the same care and supervision as have been bestowed in those towns where the pail system is cited as successful. It is the misuse of the water-systems which alone renders them open to condemnation. It must, moreover, be borne in mind that all other methods of dealing separately with house sewage can only be adopted as supplementary, and not as a substitute for the water-carrying of sewage, the liquid sewage of a town almost always containing the largest share of impurities.

Water-carrying of sewage.

Removal in sewers depends on the water-supply.

The facilities which a regular water-supply affords for the removal in sewers has caused such methods to be adopted with too little regard to the ultimate disposal of the sewage; and where, in countries like England, with an increasing population, it is allowed to flow in a crude state into neighbouring streams or rivers, the pollution of the rivers (especially those of small volume) has become intolerable. Even where the discharge is so arranged as not to inconvenience the inhabitants of the town, the nuisance is only removed to those who live further down the river, who in many cases not only suffer discomfort, but find their supply of drinking water fouled beyond endurance. So glaring has the evil become in England, that the Rivers Pollution Prevention Act has been (1876) passed to forbid the discharging of crude sewage into rivers; and the sea, in cases where the sewage is a nuisance, is included in the prohibition. Although in England, consideration for the vested interests of manufacturers has prevented the same interference with the fouling caused by trade refuse, legislation has been directed towards a reduction of this evil also, and if, to avoid infringement of the law, manufacturers discharge their trade refuse into the public sewers (thus casting upon the community the burden of disposing of it), the same Act of Parliament provides for their contributing to the expense. As such legislation has occurred at a time when the drainage of towns has been enforced by other sanitary enactments, urban authorities have found themselves in peculiar difficulties. And as the drainage of a district must eventually reach the rivers, purification through the natural filter of land, or by artificial means, becomes necessary.

Pollution of rivers.

Rivers Pollution Prevention Act.

Fouling caused by trade refuse.

Stringent enactments in England.

Means for cleansing and drainage.

The arrangement of houses and streets in the European manner, with an established water-supply, being accepted, it may be assumed that removal in a liquid state is in the majority of cases the most preferable method available, and the following are briefly the means necessary to the proper cleansing and drainage of a town:—

Street cleansing. 1. The streets must be properly sloped, and channels provided for conveying the rain-water through gratings into underground drains, the openings being properly provided with stench-traps or deodorisers.

House refuse. 2. Proper regulations must be made for the periodical removal of ashes and other house refuse; and for the removal from streets, markets, and slaughter-houses, of snow, filth, garbage, and rubbish.

House drains. 3. Every house must be provided with suitable domestic fittings, and means for the conveyance of sewage into proper drains.

Arterial sewers. 4. Sewers of proper shape and size, to which the house drains must communicate, must be constructed in every street, converging into larger arterial sewers, and there must be a sufficient water supply to ensure a proper flow and periodical flushing.

Disposal of sewage. 5. The liquid sewage must be conducted either—

See page 193 (*a*) Into the sea beyond low-water mark.

See page 194. (*b*) Into tidal or other rivers of sufficient volume to carry away the sewage without excessive pollution.

See page 196. (*c*) Directly on to land and disposed of by irrigation.

See page 200. (*d*) Or into precipitating tanks for treatment by chemicals: the effluent, more or less purified, passing directly, or after filtration through land, into a river or the sea; and the residuum—more or less effective as manure—on to land.

The above means may be further explained as follows:—

Bye-laws for streets. 1. In most civilised towns there are established regulations or bye-laws for the width and formation of streets, and for their drainage; and where new lines of houses or streets are constructed by private persons, conformity to the bye-laws is a condition precedent to the streets being opened for traffic and taken over for future maintenance by the municipality.

Removal of house refuse. 2. The removal of sweepings from streets; of ashes, bones, broken earthenware, and other domestic rubbish from houses; and of garbage from markets and *abattoirs*, is almost as essential to health as is the riddance of sewage. The removal of refuse is generally

By whom managed. managed by municipal officers, who employ for the purpose either workmen at day wages, criminals, or paupers; or by contractors, who, providing labour, carts and appliances, are paid either by money or by the refuse which they remove.

Accumulated refuse a source of disease. Although in most towns there are such arrangements for dealing with refuse, its presence in the streets or near houses before removal, and its accumulation in the vicinity of the town afterwards, are fruitful sources of disease; and too often the evils are perpetuated by the building of new houses on or close to land formed of decaying rubbish heaps. In those cities where waste land is unobtainable, various methods have to be adopted for disposing of the refuse, and, except where it is all thrown into the sea or buried, it is generally only by an elaborate division into classes that the whole can be got rid of. Indeed, in large cities like London or Paris there are few persons, even among those officially connected with sanitary affairs, who are fully aware of what does become of the refuse. Although in some parts of London the collection and disposal of the refuse are entirely in the hands of contractors, who have by experience discovered the various ways in which the refuse can be utilised, in most of the districts the work is done entirely by the municipal authorities. After picking out the old metals and bones, which have a ready sale, the harder substances, like broken crockery, are utilised for road-making; cinders or ashes are sold to brick-makers; and market garbage and street-sweepings are sold or given to farmers as manure. In some of the London districts, the sorting of the refuse has, by a liberal expenditure on buildings and sanitary appliances, been rendered as harmless and inoffensive as possible to the workpeople, who are principally women. Machines have even been devised for separating the various classes of refuse, but though worked with some success, they have proved a nuisance in the vicinity of dwellings. The "slop" or road-mud, which contains so large a proportion of road detritus, is in some cases washed for the sake of the sand in it, which can be used for mortar; but in most cases it is utilised for the raising of land or embankments, or in road-making as a substratum to the harder materials. The last resource of carrying the refuse in barges and discharging it into the sea, is seldom resorted to.

Subdivision of refuse.

Refuse, how disposed of.

Separation by machinery.

In several English and some foreign towns where carriage to suitable waste land is expensive, and other means have proved insufficient or unhealthy, it has been attempted, with increasing success, to deal with such substances by *fire*, and as burning in an ordinary furnace would be difficult or offensive, special furnaces have been devised for the purpose. The process may be shortly described as follows. The refuse is divided into two classes—the first including old glass, iron, and similar hard substances; and the second, street sweepings, with vegetable and animal garbage. The first, or harder substances, are placed in a furnace so contrived as to burn them completely with little or (according to their kind) no other fuel, and

Refuse treated by fire.

Burning of hard substances.

Results of fire-treatment. the resultant is a hard semi-vitreous clinker and a small proportion of ashes. The clinkers may be used for road-mending, but generally they are ground up, and, when mixed with lime, form an excellent mortar: the hot products of combustion are utilised for raising steam to drive a mortar-mill or other part of the apparatus. **Burning of garbage.** The second, or garbage class of refuse, is heated gradually up to redness by the action of gases in furnaces having but a small supply of air, and though the heat is sufficient to destroy all germs of putrescence or disease, the refuse, owing to the non-supply of air, is merely charred and not consumed, and when taken from the furnace is, as rough **Resultant charcoal.** charcoal, valuable as a disinfectant or deodorant. In many towns the contents of ash-pits furnish sufficient fuel for the furnaces, but where no such supplies are available the cost of fuel must be incurred, though the quantity required is very small in proportion to **Sewage treated by fire.** the refuse treated. The heat generated by these furnaces has been utilised for the concentration of the contents of sewage-pails in those towns where the pail closets are in use, by means of the concretor—a form of apparatus which secures the evaporation of watery liquids at a low temperature; and an inodorous manure of considerable value is obtained. The fire methods above described have proved to be inoffensive, and—owing partly to the economy of the process, and partly to the value of the products—cheap also. While, however, these methods may be almost self-paying, a considerable capital expenditure is necessary for the apparatus. A complete establish- **Cost of fire apparatus.** ment for treating every day 50 tons of refuse would cost (in England), including buildings and everything but land, about £3,500, and if apparatus were added for dealing with the pail closets of 60,000 persons, a further sum of £2,500.

3. The sanitary fittings of houses, and the proper connection of the house-drains to the public sewers, are of primary importance, **Bye-laws for house fittings and drains.** and bye-laws which embody the necessary regulations are an essential part of all municipal drainage schemes. Such bye-laws define different kinds of buildings, prescribe the strength of walls, the ventilation of rooms and offices, and the shape, size, and position of drains, and their connection to the public sewers; and although the owners or builders of houses have to bear the cost of all the arrangements, it is a usual regulation that the necessary sewer connections (in order that they may be effectual) shall be made by the servants of the municipality.

4. In regard to the kind and arrangement of sewers, much valuable

experience has accumulated during the recent years of municipal improvements, and well-established rules for the shape and size of sewers, and the fall which is necessary for a certain flow, are available for future guidance. The importance of ventilating all sewers both public and private, and of properly trapping all sewer-connections, has become more thoroughly appreciated. Portland cement concrete has in some cases (both in Europe and America) been substituted with advantage for brickwork in sewer construction and for stoneware in drain-pipes. Engineers are also assisted by the numerous inventions of stench-traps, deodorisers, and other sanitary appliances, conducive to cleanliness and health.

Improvements in sewers.

Ventilation.

Concrete.

See also page 102; and in Part II., PORTLAND CEMENT.

5. In regard to the different methods enumerated on page 190 for the disposal of liquid sewage, it may be said that:—

(*a*) *The Sea as a receptacle for sewage* is generally preferred when it is contiguous to the town, for though sewage valuable as manure should not be thrown away or wasted until full consideration has been given to plans for using it on land, the trouble and expenditure necessary to such utilisation generally appear to outweigh the promised results. In many English coast-towns the method of discharging the sewage into the sea is inefficient and dangerous to health; but by legislative enactments, the local authorities will be compelled to amend defective systems. In the coast-towns of other countries, the standard of efficiency is generally much below that of England. For instance, the sewage is often offensive when it is discharged into the sea in the immediate vicinity of dwellings, or at a point above low-water mark, or where—as often happens in an inland sea, or in a land-locked bay or gulf—there is little flow of tide, or where the currents are principally in-shore. Such evils may generally be rectified by extending the discharge-pipes further into the sea, or by conducting the sewage to an outfall on the coast more remote from the town, or to a point where the currents are more favourable; and such precautions sometimes involve the construction of pumping-engines for raising the level of the sewage. During the time that the outlet is closed by the tide, the sewer (although the sewage may be expelled) becomes in effect a large cesspool, and special precautions—sometimes involving great expense—are necessary to ventilate the sewer and prevent the foul gases from rising through the drains into the streets and houses. When, owing to special circumstances, the discharge of crude sewage into the sea cannot by any of the above means be rendered in-

Discharge of sewage into the sea.

See page 186.

Inefficient methods.

Remedies.

Ventilation of tidal sewers.

offensive, then a certain preliminary treatment of the sewage, such as is presently described in connection with its discharge into rivers, becomes necessary.

See page 201.

Discharge of sewage into rivers.

(*b*) *The discharge of sewage into Rivers* has been the method almost invariably adopted in towns not situated on the sea. In England there are none but tidal rivers into which crude sewage can be properly discharged, for although a running stream has wonderful powers of recuperation, offensive mud banks are deposited; and as the population is generally dense, and the rivers small, the sewage is inevitably a nuisance to towns and villages below. In new or sparsely-peopled countries the crude sewage of a town may be discharged into inland rivers; but evil results cannot be avoided, and as population increases, the fouling of the stream will, as it has done in England, prove a nuisance.

Evil results.

Strong current required.

See HARBOURS, *page 101.*

Shoals formed.

Even where there is a tidal river of large volume, sewage can only be inoffensively discharged, if the current be strong enough to bear it quickly away into the deep sea without depositing it on the banks or shoals. The circumstances which cause a bar to form by natural deposition at the mouth of a river apply to the suspended matter in the sewage also, but in sewage there are heavier and more adhesive particles than the natural alluvium, and the liability to form shoals is proportionately increased. Where the drains discharge directly into a river as it flows past a town, and especially when such discharge is continuous, the stream must obviously be fouled, and dredging to remove the banks probably rendered necessary; the degree of nuisance being measured by the volume and velocity of the stream as compared with the amount of the sewage poured into it.

Discharge of London sewage into the Thames:

See also page 183.

Pumping-stations.

Catch-pits for road-grit.

The manner in which the sewage of London is discharged into the Thames will illustrate the methods which have been considered efficient. Up till the year 1860, local sewers emptied into the Thames at all parts of its course through the metropolis, and the fouling of the stream became at last unbearable. Since that date long lines of main sewers have been constructed on each side of the river, which intercept all the previously existing sewers, and convey their contents to points about twelve miles below London Bridge, where the river runs for a considerable distance between uninhabited marsh lands; pumping-stations at various points on the route raising the sewage to the level necessary for a proper flow. At the stations, proper means are taken by a system of scavenging and of catch-pits to remove large substances and the heavier silt or road-grit, and the crude sewage with only this preliminary treatment passes into the river. In deciding upon the capacity of the main sewers, a ¼ in. rainfall in each 24 hours was assumed. Exclusive of heavy rains, the ordinary flow of sewage amounts to 120 millions of gallons per day. In dry weather the discharge is made only for about two hours after high-water, but the ramifications of the sewers are so complete, and the rain-water finds its way to the outfall so quickly, that the main sewers have proved to be not large enough to store the water between the tides, and when there is more than a slight rainfall the discharge into the Thames becomes of necessity more or less continuous. Moreover, with heavy rains the pumping power is insufficient, and the safety-outlets which have been provided from the local sewers into the old river outfalls are called into use, though of course the discharge from them is at such times much diluted. The river, in its course through the metropolis, has been greatly purified, and where foul odours and offensive mud-banks formerly prevailed, the only impurities are those from shipping and small local drainage along the riverside which cannot be avoided; and the banks at low water exhibit an almost clean shingly beach. But it has been found that the sewage matter floats up and down with the tide, taking many days to reach the sea, and that during that time much of it is deposited on the bed and sides of the river. If this deposit occurred only below the outfalls, constant or periodical dredging would probably be the cheapest remedy until an increasing riverside population rendered such means ineffectual; but it is found that the sewage matter is carried by successive tides up the stream; and although the fact of its presence as far up as London is (1877) questionable, it is a nuisance to the inhabitants on the river banks between London and the outfalls. While, therefore, the construction of the main sewers may be considered as a great work admirably executed, the method of disposing of the sewage is not successful; and it can hardly be doubted that the provisions of the Rivers Pollution Prevention Act will be applied to amend it. The remedy will probably be sought either in the extension to the sea of the main sewers, which will discharge their contents, either directly into the sea or on to the large area of waste and sandy shore which the estuary of the Thames presents; or, as an alternative, the sewage may receive a preliminary chemical treatment, either at the present outfalls or lower down, so that only a sufficiently-purified effluent may reach the stream, in the same way as has been successfully done at Rio de Janeiro. The

Provision for rain-water.

Sewage discharge continuous.

Advantages obtained.

Incomplete results.

Mud deposits.

Dredging.

See DREDGERS, *in Part II.*

See page 189.

Further works necessary.

See page 202.

road *detritus* is one of the difficulties in the dealing with London sewage, for as most of the streets are paved or macadamised with granite, the quantity washed into the sewers is very great, and notwithstanding the precautions (already involving trouble and expense) at the outfalls, much of it passes into the river and sinks to the bottom; and although the scour of the current keeps the main channel clear, banks are formed which have to be removed by dredging. The amount of London sewage to be dealt with is so great, that discrimination is needed in rejecting the outfall system as inapplicable to other places. But where no river of sufficient volume (in proportion to the sewage) is available, method *c* or *d* must be resorted to.

Deposit of road-grit.

Involves dredging.

London not a fair precedent.

Sewage land-irrigation.

(*c*) *Sewage irrigation* has been attempted in many ways, and if looked at only as a means of riddance, the experience of the thirty years ending 1877 with the sewage of English towns proves that in the majority of cases such a method either by itself or when allied with other means may be adopted. When, however, the pecuniary results are investigated, it is found that only in rare cases, where there is a combination of favourable circumstances, does the use of the sewage as manure repay the cost; and even where the farmer may use the sewage profitably, the question is, for the town or municipality, narrowed to a calculation of the annual expenditure which must be incurred; the least favourable cases showing that some other and less expensive manner of disposal must be adopted. The circumstances that are favourable to a profitable use of sewage as manure are the following: the contiguity of agricultural land or waste land that can be fertilised, and facilities for conveying the sewage: such a level and position of the land in regard to the town and to the line of sewer, that the sewage can be brought, without pumping, to the site, and that it will, without being artificially raised, flow on to the land, which must be so situated that it can be under-drained or possess a natural under-drainage of from 4 to 6 feet deep. The price or rental of the land, and the expense of preparing or laying it out to receive the sewage, must be moderate. There is often a great prejudice against selling or letting land for sewage irrigation, and prices or rents are demanded far in excess of its agricultural value; and if, for any reason, it is impossible to acquire at a reasonable price a sufficient area in the vicinity of the town, it becomes necessary, to carry the sewage long distances.

Profit cannot be obtained.

Favourable circumstances enumerated.

Levels.

Price or rental of land.

Unless there be a falling gradient along the line of sewer, one or more pumping-stations are required, and an annual expenditure, as well as an increased capital outlay, is incurred. Liabilities of this kind are among the various causes for the great and unremunerative outlay sometimes incurred by municipal or sanitary authorities on sewage farms. The expenses of laying out or adapting land are also sometimes a great burden on irrigation schemes. As much as £200 per acre has been expended in cases where £10 per acre is all that could properly have been afforded. On the other hand, there may be cases where, owing to the limited quantity of land available (and other methods of sewage disposal being more costly), an elaborate preparation of the land as a filter-bed may be the best means left to adopt.

Pumping-stations.

Expenses of adapting the land. *See also page 154.*

Filter-bed.

The quantity of land required for the sewage of a certain population varies according to the quantity and kind of sewage, and the character of the soil. The quantity of sewage depends upon the water-supply and the rainfall, and is in English towns generally some amount between 20 and 70 gallons per head per day; 30 gallons being a fair average, the larger the quantity the greater of course the dilution. If the land be calculated according to the necessities of agriculture—as for corn or ordinary grass—one acre would not require as an average daily supply more than 2,000 gallons of sewage; for in English towns where modern systems of sewage-irrigation have been tried with a view to obtaining a farmer's profit, an average of one acre of land for sixty of the population has been found requisite; but where purification of the sewage is the sole object in view, and where the sewage is subjected to preliminary treatment, the same area will, under favourable conditions and proper management, serve for a much larger population.

Quantity of land required.

Gallons of sewage per acre.

Vegetable produce has generally a high value in the vicinity of large towns, and sewage has been successfully applied to mangold-wurzel, osiers, and Italian rye grass; but in the majority of cases the latter has been found to be the crop most easily obtained, and the one least liable to injury by sewage in large quantities.

Crops suited for sewage.

The value of crude sewage as manure depends mainly on its degree of dilution, and in England the average value set upon it (if the best Peruvian guano and the superior kinds of phosphates be taken as standards of value) has varied from 1d. to 3d. per ton delivered on to the land to be irrigated. Later experiments diminish even this estimate of value, for it has been found that of the nitrogen

Money-value of sewage as manure.

which (as in guano) is the principal fertilising ingredient contained in the sewage, at least 50 per cent. passes away in the effluent water unabsorbed by land or crops after the sewage has filtered through the soil. If in England such are the pecuniary conditions, they must be less favourable in those foreign countries where agricultural land is less dependent on manure, and where crops have a lower value; while, on the other hand, of course, there may be cases where there is barren land near a town which, by sewage-irrigation, may be rendered fertile.

Barren land benefited. *See* RECLAMATION.

The advocates of land-irrigation recommend as a remedy for the depreciation in value caused by extreme dilution of sewage, the keeping of the domestic or richer sewage separate from the ordinary drainage of the town, either by using the "dry earth" or "pail" methods, or by providing separate systems of sewers. The former methods, while applicable in villages and places with contiguous agricultural land or even—under elaborate management—in towns, is, as has been said, not the best suited for general adoption in crowded localities provided with a regular water-supply. There is much to be said both for and against the duplicate-sewer system. For the sewage alone, conduits may be made only of a size suited for their every-day duty, and not, as in the "common sewer" system, large enough for the maximum flood waters, which may but rarely occur: where pumping is necessary for raising the irrigating-sewage, a much less quantity would have to be raised. The sewers thus reduced would afford much less space as "gas-holders" for storing foul odours, and also would demand very much less water for flushing—a circumstance of particular value in towns not provided with a regular water-supply. On the other hand, the duplicate system is much more costly, and there still remains the question of the ultimate disposing of the rain-water with the street impurities. For the street scourings contain the worst of the sewage, especially in towns where house slops are emptied directly or through gullies into the street gutters; the character of such gutter-sewage being at its worst during and immediately after dry weather, before heavy rains have flushed the gutters. In tropical climates it is impossible to provide for the heavy rains in the ordinary sewers. A provision for $\frac{1}{4}$ in. of rain per day is generally considered sufficient in England, but in some parts of India 12 in. of rain will sometimes fall in a day, and even 3 in. in an hour. In cases of this sort the street channels and water-courses must be arranged so as to give an uninterrupted flow to the rivers without flooding either streets or houses.

Sewage separated from rain-water.

See page 188.

Smaller sewers suffice.

Advantages obtained.

Duplicate system costly.

Sewers cannot take heavy rains.

Rainfall in India.

Sewage partially separated.

A compromise between the alternative plans of common and duplicate sewers has been tried with success in some English towns, and where there is an opportunity—as when a new sewage system is being devised—of suitably arranging the works, it bids fair to be a solution of this particular question. According to this plan, the street gutters are allowed to empty into the common sewers during periods of dry weather and moderate rains, for at such times the gutter-sewage has as much manurial value as the domestic sewage, and for this reason is as ill-suited for free discharge into a river. But at each point of junction with the sewers there is a "leaping weir," so arranged that while a moderate flow from the gutters falls vertically into the common sewer, storm water rushing quickly leaps the weir, and is taken away in a separate conduit. As when such a time arrives the streets and gutters will have been already scoured of their worst impurities, the surface drainage may be conducted directly into a river to which the admission of ordinary sewage might be forbidden, and which in a time of flood may be in such a condition from ordinary land drainage, that the street overflow will have no appreciable effect upon it; the common sewers need be (in a climate like England, where provision for rain-water is two-thirds of the whole) but of small capacity; and the richer sewage used for irrigating land is then no longer weakened by dilution, or rendered formidable in bulk for pumping.

Leaping-weirs for street drainage.

Advantages obtained.

Pecuniary results of sewage-irrigation.

The pecuniary results of sewage-irrigation have been almost always unfavourable to the town authorities who have had to get rid of the sewage, for where it is offered for sale, the interests of the farmer and the municipality in regard to the periods or continuance of the sewage-discharge do not accord; while, if the municipality themselves own and till the land, the many difficulties which attend the undertaking (especially under corporate management) hardly ever allow interest to be earned on the capital outlay, and generally result in a deficit. Expense in the disposal of sewage must, in short, be looked upon as necessary, in fact, as a tribute paid to health and decency, and in inland towns where no sea or river is available for receiving the crude sewage, nothing remains but to choose from systems *c* and *d* the one which is for the particular case in view the least troublesome and expensive.

Expense unavoidable.

Although in the application of crude sewage to land its value as manure has in most cases been considered, the primary or sanitary purpose is the filtering of the sewage through the soil, so that the

Filtration of sewage through land.

effluent water which, through the ordinary land-drainage, finds its way to the stream, may be sufficiently purified. In many cases the latter purpose is alone attained, and no attempt is made to utilise the sewage as manure. This method may be expedient in cases where the available land is limited in area, and the maximum amount of sewage which the land will absorb and filter, rather than what is needed for vegetation, is the measure of quantity. There are great differences of opinion amongst engineers, chemists, and sewage farmers, as to the quantity of crude sewage which can, in cases of this sort, be so absorbed or filtered as to render the effluent water harmless enough for discharge into rivers. It has even been asserted that experiments with the sewage of English towns, show that with an established water supply—all taken with the surface drainage by one common sewer—from four to six gallons of the sewage thus diluted may each twenty-four hours be purified by a cubic yard of soil, according to its kind; so that if an average of five gallons be taken, with soil available to a depth of six feet, one acre (4,840 square yards or 9,680 cubic yards) will suffice for 48,000 gallons; or, assuming 40 gallons per head of population, for the sewage of about 1,200 persons. But although results like these may be deduced from experiments under favourable circumstances, probably not a fourth part of these quantities could be permanently treated, for the soil would either become choked and unfit for further service, or the effluent be but slightly purified. If, however, the ground be elaborately prepared as a filter bed, and regularly cleansed and renovated, such a method belongs to another category, and must be dealt with accordingly. Summarily it may be said that to effectually purify crude sewage by using it in irrigation, a larger quantity of land is required than is generally to be obtained in the vicinity of large towns; that a smaller quantity of land may be made to suffice if the sewage has already been chemically treated, or if only partial purification, preparatory to a discharge into a sea or tidal river, is in view; and that the combination of methods *c* and *d* is in most cases the best solution of the difficulty.

Measure of quantity.

Differences of opinion.

Quantity per cubic yard of soil.

Experiments inconclusive.

Conclusions.

Treatment by chemicals.

(*d*) *The treatment of sewage by Chemicals* has been tried in various ways, some simple and cheap and others complicated and expensive; but the general results, like those of sewage irrigation, have proved that, however necessary and effectual for sanitary purposes, these plans are not successful as sources of profit. The numerous attempts to show profits from such methods have not only proved fallacious, but have done much to discredit chemical treatment altogether. All the chemical processes which have been applied to sewage have for their common object the precipitation of the suspended particles, but they differ very much in the process, and in the further effects which are sought. If in districts remote from habitations sufficient space were available for depositing-tanks, the suspended particles of sewage might be separated without any chemical process, and the earliest and simplest of the chemical methods which is still in use in certain towns—that of treatment by lime—has only the object of precipitating the suspended solid matters more quickly and effectually than by mere subsidence. The lime-treatment has, however, many disadvantages, which render it quite unfit for any but rare and special cases. Lime is so absorbent as to increase greatly in bulk, and it adds to the amount of sludge precipitated; the effluent, though freed from much solid matter, is but slightly purified, and undergoes a further or second decomposition in the river to which it flows; and the residual sludge, which has no saleable value as manure, is a putrescible mud of so offensive a kind that there is great difficulty in getting rid of it. Were it not for this latter circumstance, lime precipitation might be serviceable in some cases, where lime is cheap and other materials dear, as a preliminary to land-filtration, or to the discharge of the effluent into the sea. But unless there is ample waste land immediately adjoining the precipitating-tanks, so that the sludge can be at once buried, the mischiefs of the sewage are intensified in the sludge, and there is no longer the water-carriage for its removal.

Chemical methods described.

Precipitation.

Lime-treatment.

Unfit for general use.

Residuum offensive and worthless.

The more elaborate chemical methods are directed towards the better purifying of the effluent, and the deodorising of the sludge; the disposal of the latter being the main difficulty. A combination of lime with sulphate of alumina is probably one of the most effectual of the compounds which have been proved by sufficient experience. The effluent from sewage so treated, though apparently pure to sight and smell, contains a certain proportion of soluble matter valuable as manure, so that it is suitable for land-irrigation, and the effluent after being thus filtered may be discharged into rivers without increasing the proportion of impurities which they already carry from the ordinary land drainage. These chemical processes find their best application as preliminary to such filtration, or to discharge into the sea. As instances, Coventry in England and Rio de Janeiro in Brazil may be cited. In the former case, the effluent from the sewage of 40,000 persons, containing

Lime and alum.

Sewage effluent.

Sewage works at Coventry.

a large amount of manufacturing impurities, after the precipitation process and filtration through nine acres of land, flows harmlessly into a small inland river. The sludge is inoffensive, and, as manure, is worth when dry the cost of cartage on to land. The drainage of Rio, which has a population of about 400,000, affords a rare example of works devised and successfully carried out in a large city, previously without any kind of sewers or sanitary arrangements. Situated only a few feet above the sea level, the city is surrounded on three sides by a land-locked bay, having little flow of tide, and the soil was saturated almost to within a foot of the surface. The filth from the houses and streets was emptied at night on the beach; epidemics were of frequent occurrence; and the death-rate was a high one. By the new works every house is drained into the sewers, which carry also a portion of the rain-water (that from the back-yards and housetops), and the sewage, after being lifted by steam-pumps, is chemically treated in large precipitating-tanks by lime, alum, and charcoal. There is no land available for after-filtration, but the effluent is passed through a filter of stones and gravel, and flows into the sea. Although the works are situated in the heart of the city, and notwithstanding the absence of a proper water supply, the sewage is so thoroughly deodorised that no nuisance arises from any part of the process, nor from the sludge, which (no agricultural land being available) is deposited on waste land in the vicinity of the city. One important benefit derived from these works is that the level of the water in the hitherto-saturated soil is lowered. This system has been in operation since 1863 in the city proper, and is (1877) being extended to the suburbs. The cost of the process, and of the entire drainage operations, both at Coventry and Rio, does not reach two shillings per head of population per annum, exclusive of interest on capital outlay.

Rio de Janeiro.

Rio sewage-works inoffensive.

Annual cost.

Calcutta drainage works.

In some respects the drainage of Calcutta resembles that of Rio, and the results are even more beneficial. The city is situated on a level only a few feet above the sea, and was formerly so swampy and filthy that fever and cholera were hardly ever absent, and the death-rate was conspicuously high. The alteration and improvements that have been obtained in Calcutta from well-designed sanitary works, carried out under peculiar difficulties, afford one of the most notable instance of benefits so obtained which can be found in modern times.

Elaborate processes.

Still more elaborate chemical processes have in view the giving of an increased value to the sludge as manure, or the more complete purification of the effluent; the former result being sought either as a distinct source of profit, or, as is more often the case, to recoup the outlay for purification. The attempted combination of sanitary purification with a commercial profit has in many cases caused the failure in both respects. If a high standard of purity in the effluent water be demanded, and if it be very difficult or expensive to obtain land for filtration, then the outlay for elaborate chemical processes may be justified; but the most that can then be hoped for is that some of the outlay may be recouped by the sale of the sludge as manure; failure always attending the attempt to earn a surplus profit. By using chemical ingredients which themselves are effectual as fertilisers, the sewage sludge may be converted into artificial manure, the value of which increases in precise ratio (less the expense of waste and error in the process) to the cost of the ingredients used. The higher the value obtained, the greater will be the loss in obtaining it; but it may sometimes be expedient to enrich the sludge to a small extent to induce farmers to take it, and to give it a value which will then bear the expense of carriage. Sewage sludge may be burnt into cement, and where there is a demand for such material, the cost of so treating it may be repaid.

Profit cannot be obtained.

Sewage sludge fortified by chemicals.

Burnt into cement. *See page 192.*

The cost of town-drainage works must obviously vary within very wide limits, according to the nature of the works required, and the thoroughness with which they are carried out. The capital outlay has not alone to be considered; and a comparison of the cost of works in various towns is incomplete, unless the annual expenditure for working and maintenance be also reckoned. In a gravitation scheme where the sewage flows directly on to the land, or into a sea or river, the cost for maintenance need be but small; but where pumping-stations are required, or processes of precipitation, deodorising, or other treatment carried on, the annual charges may be considerable. In London, the cost of the main-drainage works and pumping-stations was four millions, or about £1 per head for the population benefited. The annual cost of working and maintenance is (1877) about 1s. per head of population. In England, it may be said generally that the larger number of modern drainage-works have been carried out at some cost between 15s. and 25s. per head of population; and the annual expenditure in any but ill-managed or peculiarly difficult cases, is some amount between one and two shillings per head, exclusive of interest on capital.

Cost of town drainage.

Annual expenditure.

Cost of London main-drainage.

Capital outlay on English works.

Annual expenditure.

Provision for future extension.

The expediency of providing for a growth of population must obviously depend upon the probabilities of increase, and the comparative cost—according to the nature of the scheme—of constructing large works at the commencement, or of adding to them afterwards. As in constructing long lines of main sewer it is the intention to intercept all the sewage of the district traversed, it is almost always expedient to allow for a growth of population and increase of houses; the additions to be provided for being measured not only by the water-supply which such additions will carry off, but the additional rainfall or storm-water which new ramifications of sewers will bring into the arterial sewer. But as population increases, so will the area of rateable property, and the capital to be paid off will annually diminish. In some cases, one system of drainage may be made to include numerous towns or villages; the expediency of such a course depending mainly on whether the levels are favourable to lines of arterial sewer and one common outfall. Villages or towns situated along the same valley may be thus conjoined, and provision may be made in the capacity of the main sewer for intercepting the drainage of new districts which may be afterwards added.

Rate-income grows with population. *See* RATES, *on page 183.*

District arterial sewers.

A proper scheme for town drainage can only be made after careful survey and examination by competent engineers. But to assist an engineer in advising as to the best methods, and contractors in estimating cost, information of the kind described in the following pages must be supplied; and according as the information is full and correct, so probably will the designs and estimates be complete and trustworthy. In few cases, however, will an engineer complete his schemes, or a contractor bind himself to an exact amount, until the conclusions arrived at have been verified at the site. The information needed is as follows:—

Careful surveys necessary.

Information classified.

Plans and levels.

1. A plan of the town on as large a scale as possible, showing the area to be drained, the main and cross streets, and the lines of houses; and with references to the character of the soil and sub-soil at all points. The levels of the different parts of the town as relating to some datum line should be marked on the plan, especially (if there be a river) down-stream; and sections at various places should be given, by which the gradients of the streets and the contour of the slopes may be understood. Upon the plan should be marked the streets, or other lines of route, which are presumably the best suited for the main or arterial sewers. The proposed

outfall for the sewer, if in or near the town, should be marked on the plan; but if at some distance, a map (if necessary, on a smaller scale) should be furnished, on which the outfall and routes to it, with their levels and gradients, are indicated.

Coast-line.

2. If the sea is available as a receptacle, the coast-line must be shown on the plan, with the places which appear most suitable for the outfall; the slope of the shore at these points, and the nature of the beach and sea-bed, being carefully described. Shoals or banks likely to be affected, or to obstruct the flow of sewage, must also be shown. The different levels of tide should be indicated (including extraordinary tides), the force and direction of prevailing winds and currents, and the direction—as ascertained by floats—which liquid or solid matters discharged into the sea will take during different winds or tides. Any existing sewage-outfalls should be indicated on the plan, and the past general results described.

Tides and currents.

Volume of rivers.

3. If the sewage is to be discharged into a river, information should be given as to the volume of water, and the various levels of tide or flood, in reference to the level of the town or district to be drained; the strength or speed of the current at and for some miles below the town; and whether, and at what places, the river water is taken for drinking purposes. The slopes and material of the banks and river-bed, as shown by cross-sections, should be furnished, together with particulars of sites suitable for sewer-outfall or pumping stations.

Population.

4. The number of the population, with statistics of the past, present, and probable future rate of increase. The relative density of the population in the different quarters of the town: the approximate total rental value of the houses: the rent generally paid for the different types of houses: and the rateable value of the district to be drained.

Rental value of houses.

Existing methods of drainage.

5. The existing methods of house drainage, and the means used for the removal and disposal of sewage, and for removing refuse from houses, streets, factories, markets, and *abattoirs*, should be carefully described; and drawings furnished giving in detail examples of one or more types of houses, with their domestic sewage arrangements. A description should be furnished of any manufacturers' or trade refuse which may form part of the sewage to be dealt with.

Existing sewers described.

6. If sewers already exist they should be described, with their size, shape, and the materials of which they are made; the fall at which they are laid; whether the sewers are ventilated, and if so, how; whether they receive surface water and road grit; whether

the presence of road material, such as sand or grit, in the sewer has already caused trouble; whether the town is paved—if so, how, and how much of it; if not paved, the material of which the roads are composed.

Road paving.

Water-supply.

7. The nature, amount, and source of the water-supply, and the depth below the surface at which water is reached in the town and in the neighbouring country of lower altitude. If waterworks are established, whether the supply is constant or intermittent; and what is the quantity supplied per day for domestic, trade, and municipal purposes. Existing water or gas pipes in the streets should be indicated on the plan of the town. The amount of rainfall at different seasons of the year should be given if possible, and the maximum known fall in twenty-four hours and in one hour, and full information generally concerning the effect of heavy rains which flood the streets, and for which special provision must be made in the sewers and outfall. If there be dry and rainy seasons, any existing systems of storage should be described.

Rainfall.

Reasons for new works.

8. The immediate reasons—whether injury to health by refuse remaining in close proximity to houses, or the pollution of rivers, or any other causes—which render the proposed new works necessary; and also whether the action of the municipality is voluntary, has been suggested by the inhabitants or by promoters, or has been guided or enforced by legislative enactments.

Laws or statutes.

9. Copies of the law or statutes, if any, under which the works have been ordered, or under which they must be constructed; and of any present or contemplated bye-laws on sanitary matters.

Occupations of the people.

10. The trades, occupations, and habits of the inhabitants should be described, so far as they may affect any scheme of drainage; whether police or official regulations will be granted to enforce the proper use of new methods; whether conformity to such regulations may be relied on, and the legal remedies which will be available.

Land for irrigation.

11. If the disposal of the sewage on land is contemplated, the geological formation and the nature of the soil in the vicinity of the town should be described; whether the land is waste or cultivated; whether drained, and if so, at what depth, and to what stream the drainage is taken; the methods of cultivation in vogue; the kind and rotation of crops; the markets at which they are sold, and their value there; whether crops of other kinds which sewage manure would assist would be saleable; the kind and value of the manure which is used; the price at which agricultural or waste land avail-

Crops.

Manures.

able for sewage operations could be rented or purchased; the tenure upon which it could be held; and any other information by which the possibility and economy of sewage-irrigation might be estimated.

Sites for pumping stations.

12. If pumping-stations are contemplated, or artificial methods of filtration and purification, they should be described, the proposed sites indicated, the probable cost or rent stated, and information furnished as to the kind of dwellings and class of inhabitants in the vicinity, and the likelihood of opposition to sewage works on the ground of nuisance.

Climate.

13. The nature of the climate, and the extreme temperatures at different seasons, should be described.

Labour and materials. *See also page 70.*

14. Local information as to labour and building materials available, and specially in regard to concrete; the prices at which lime, sulphuric acid (vitriol), sulphate of alumina (or the shale, or clay, from which this can be made), and other agents for sewage-precipitation and deodorising could be purchased.

Financial.

15. The financial conditions under which it is proposed to construct the works, the periods of payment or terms of concession, and information generally of the kinds already specified.

[*See also* IRRIGATION: RECLAMATION: WATERWORKS: *and*, *in* PART II., PUMPING-ENGINES: PIPES: PORTLAND-CEMENT.]

CHAPTER XI.

GAS-WORKS.

Gas-works necessary.

Growth of revenue.

Gas-works remunerative.

Monopoly profits.

Municipal gas-works.

UNLIKE the water-supply of towns, which satisfies a necessary and obvious want, the supply of Gas is at its first introduction considered as a luxury or convenience, the use of which will be optional and problematical. But when Gas-works have been well established, and a town has for some time experienced the advantages of gas lighting, the convenience becomes almost a necessary for universal adoption; and the growth of revenue is generally more rapid with a gas undertaking than with water-works. Gas-works are now established in all the large cities of the civilised world; and in Europe, even small towns unlit by gas are becoming every year more rare. In the earlier days of gas making, losses were frequently incurred: in later times no undertakings have, in Great Britain, been so constantly remunerative to the capitalist, and the shares of the various companies have a marketable value generally above par; the average rate of dividend paid to investors exceeding that derived from railways or any other public works. As the natural tendency of competition is to reduce the profits of all enterprises to a common level, the maintenance of high profits in gas-works must be explained mainly by the fact that such enterprises have to a large extent the advantages of a monopoly. So much is this beginning to be felt, that the instances are (1877) increasing of municipal bodies constructing gas-works or purchasing from companies works already established, with the intention of supplying the gas at cost price; or of earning a profit, and applying it to public purposes or to the reduction of taxation.

The purchase-money is almost invariably borrowed, and in some

Repayment of loans.

See pages 98 and 183.

Lenders depend on the security of the rates.

See page 183.

Terms of years for loans.

instances there is a tendency to spread the periods of repayment over too many years. Although in the case of sanitary works or water-works which will be of permanent advantage to the community, the transference of a large proportion of the burden of repayment to a future generation may be justified, a continuance of the existing system of gas-lighting and manufacture cannot in an era of scientific invention be looked upon as certain. Financial Societies, Insurance Companies, and others who—as well as the Public Loan Commissioners—are the principal lenders of money to municipal bodies, would be indisposed therefore to advance funds for the purchase or construction of gas-works, the revenue from which is put forward by the borrower as a valuable security, were it not that the public rates are also answerable for the debt; and it is the facility for borrowing which this latter security affords which is one of the chief inducements to the municipal authorities to borrow. As, however, the public rates have, in many cases, been already deeply pledged for the repayment of loans for sanitary purposes, any failure in the gas undertaking might at a future day press heavily on the community. A shorter term of years for gas loans than that (generally thirty years) usual for the repayment of other advances, would appear to be the more prudent course, rather than the longer term often asked. The ease with which money is borrowed in England on the security of the rate-income, which—within a very wide range—can be increased till the liabilities be satisfied, must not be taken as a precedent in places where there is no such latent security.

Gas-works owned by municipality.

See WATER-WORKS, *page 166.*

Reasons in favour of municipal management.

The construction and ownership of gas-works by a municipality cannot be justified by the same arguments as warrant its engaging in such undertakings as water-supply or sanitary works, which, as all important to the health of the community and as interfering with individual rights, may with some advantage be established and controlled on the public behalf. The reasons generally adduced in favour of municipal gas undertakings are—that, as the supply of gas must almost necessarily be a monopoly, it may with advantage be retained in the hands of the authorities; that if the sewers and water pipes are in official hands, so also should be the gas mains; that better and purer gas will be the primary object instead of gain; that the public lighting will be better and more cheaply maintained; and, finally, that the profits can be usefully and legitimately applied to public purposes. There is much force in these arguments, but on the other side it may be said that the last three reasons would apply to almost any kind of manufacture; that experience does not recommend the management of manufacturing enterprises by public bodies; and that economy and good management are better assured when stimulated by the watchfulness of private capitalists. It is questionable, therefore, whether the interests of the inhabitants may not be better served by allowing private capitalists to establish and control the gas-works, subject to strict conditions as to the price and quality of the gas, rather than by involving the public revenues in an uncertain or speculative enterprise. Moreover, where a corporation obtains profit from the sale of gas, there is too often a tendency to jobbery in the expenditure of the funds; for, so long as the undertaking shows a margin of profit, strict investigation on behalf of the public is neither likely nor easy, and an unnecessarily high price may be maintained. If it becomes usual to look upon the gas profits as a source of revenue, a system of indirect taxation is established, which, whatever its apparent advantages, is in most countries of English origin (though not in towns accustomed to *octroi* duties) the introduction of an entirely new principle in municipal affairs; especially as such taxation is levied not according to wealth or rental, but according to the accident of gas consumption. Where, however, the gas supply of a town is in the hands of two or more companies who are not disposed to amalgamate on terms favourable to the public, the disadvantages of dual management may form a special justification for municipal interference. But as the shareholders in a profitable gas company will demand a compensation beyond the mere return of their capital, the municipality will commence operations under less favourable circumstances than did the original proprietors.

Reasons against municipal gas-works.

Risk of jobbery.

Gas profits in effect a tax.

See page 182.

Dual management undesirable.

A plan is adopted in some towns of dividing in equal parts between the shareholders of the gas company and the municipality all profits, after a certain dividend has been paid to the shareholders. This arrangement is, for example, applied in Paris, and combines the advantages of private management with profit to the public. The municipality may justify their claim to a share on the plea that it is only a fair return for the monopoly they have granted, especially where they have given also facilities, immunities, or guarantees. This plan is, however, still open to the objection that the surplus revenue so divided ought, with greater justice, to be applied to the reduction of the price of gas to the consumers—a principle which has been satisfactorily applied in London.

Profits divided with municipality.

Surplus profit shared by consumers.

See page 213.

Foreign gas-works.

In new and foreign countries, municipalities rarely undertake the establishment of gas-works, although by favourable concessions they encourage private enterprise. Unlike railways and other large undertakings, which generally require the combination of many capitalists, gas-works, especially those in towns of moderate size, can in many cases be constructed wholly or in great part by the money of local investors, for whom, indeed, such undertakings are specially suited. But in many foreign towns, although the undertaking is one under their own eyes, the people are not enterprising enough, and outside aid has to be sought to provide some or all of the capital, to design or construct the works, and often to perform all these functions. If there is a competent local engineer, it is sometimes only necessary to import the apparatus, and the works can be carried on without other foreign aid. A contractor will sometimes construct the works for deferred payments; or, with his own money or that of capitalists who assist him, will take upon himself the entire charge and property in the undertaking. In this case, he and those who act with him will generally look for their profit to the transfer of the undertaking when in operation to a joint-stock company; a perfectly proper arrangement, though sometimes such transfers have been discredited by the excessive profits that the price has included. There are many investors who, while unwilling to assist in the earlier and uncertain stages of an enterprise, will join it when they see it earning revenue; and, in such cases, the more venturous contractor will reap a legitimate profit by selling the gas-works to the company at an enhanced price; that is to say, for a sum higher than that for which he would have been willing to execute the works if punctual payments in money had been secured to him during construction. As the ultimate value of the gas-works will depend upon the net revenue they produce, and on the proportion which this bears to the capital invested, the speculative contractors or capitalists who provide the money, will—if they are acting fairly—only do so after assuring themselves that the conditions are such as afford reasonable hope of sufficient profit. In not a few cases, both in England and abroad, gas-works are permanently held by the contractors who made them, and who by themselves, or with their friends, are content to leave their capital thus invested.

Suited for local investors. *See page 21.*

Outside aid required.

Cost defrayed by contractor. *See page 39.*

Sale of gas-works when completed.

Profits gained by sale of works.

Gas-works owned by contractors.

See Chapter II.

Referring to the various kinds of concessions already described, it may be stated generally that municipalities rarely grant subsidies for gas-works, and almost as rarely guarantee interest on capital,

Guarantees. *See page 18.*

Facilities granted. *See page 25.*

Monopoly. *See page 27.*

Right of preemption by municipality. *See page 37.*

although where gas-works are much wanted, a guarantee may be given for the first two years, or till the works are in operation. The concessionnaires have therefore to be content with the facilities or other encouragement afforded them, which may give to the undertaking the advantages of a monopoly, and upon the nature of which the profits and security of the investments will largely depend. Capital once sunk in gas-works cannot be recovered; and those who propose to establish gas-works in a town naturally desire, as some security for their investment and in return for the risks they incur, protection against the competition which might arise if the enterprise should prove profitable. In the public interests, the granting of a monopoly is justified by the peculiar nature of the enterprise, and by the inconvenience which would arise if rival companies were to erect works and dig trenches for pipes in the public streets. It is a usual condition, therefore, that the municipality shall grant a monopoly for a term of years, say from 30 to 80 years, or—if other gas-works be not absolutely prohibited—the exclusive privilege of laying pipes in the public streets during this period. In effect, this exclusive privilege is a monopoly, which, if it does not prevent the construction of private gas-works, forbids any competition in the sale of gas to the public. The right of buying up the undertaking at the end of, or during the period of, the concession is sometimes reserved by the municipality; and in such cases it is always desirable that the terms of purchase shall be clearly expressed from the first.

Prescribed limit to gas profits.

Assured profits not conducive to economy.

English system amended.

It is a customary stipulation that the dividends of a gas company shall not exceed a prescribed maximum (in England generally 10 per cent.); and it is expected that the selling price of the gas shall be kept down to a rate so determined. The obvious interests of the gas company lead them, before reducing their price, to provide amply for the repairs and renewals of their works, and next, to pay to their shareholders (if the law allows it, as in England it generally does) any deficit from the maximum which may have occurred in the dividends of previous years. The interests of the gas company being thus secured, and further profit being unattainable, there is no inducement to an economy in manufacture which will be of benefit only to the consumers. The later legislation for gas undertakings in England has, however, provided the stimulus of self-interest to such economical management by permitting, for every reduction in the price of gas below a fixed rate, a corresponding addition (according to an agreed scale) to the dividends; while any advance in price beyond the fixed rate involves a diminution in the dividends; the risk to the shareholders of the latter event depending largely on any rise in the price of coal which may increase the cost of the gas.

Stimulus to economy obtained.

The profits of shareholders in undertakings where high dividends are allowed being thus practically assured, the value of their shares has risen accordingly; and when an increasing population renders an extension of the gas-works necessary, capitalists are eager to provide more money on similar terms. But as the privilege of thus investing in a profitable enterprise belongs primarily to the existing shareholders, access to such potential profit becomes at once a saleable commodity. While, however, the maximum interest on their original capital may of right belong to the shareholders who invested their money on such a condition, the power of realising in advance, at the expense of future generations of gas consumers, the difference between ordinary and gas-monopoly profits is not so clear; and an equitable adjustment of this question has been found desirable in the public interests. In England, the limitation of dividend on new capital to a lower rate than on the old (generally to 7 per cent. instead of the previously permitted 10 per cent.) has been enacted in some cases, while in others the more stringent condition has been laid down that all new shares shall be sold by auction to the highest bidder; the difference or premium above par value being applied to the cost of works, and not, as before, as a bonus to the original shareholders. This has been effected by supplementary enactments in the case of existing gas companies; and the same principle will probably be embodied in the legislation for new undertakings.

High value of gas shares.

New capital freely offered.

Privilege of investment saleable.

Future profits limited by law.

Sale of new shares by auction.

There may, however, especially in new countries where capital is scarce, be cases where the chance or expectation of prospective profits on future outlay is the very circumstance which induces capitalists to invest their money, and the inhabitants or authorities may find it impossible to obtain the advantages of gas-lighting on easier terms. This is obviously a question to be decided according to the merits of each case, but it should always be decided at the commencement, and embodied in the terms of the concession. The granting of a monopoly for a term of years, at the expiration of which the municipality acquires the property in the undertaking, or the right to demand rent or a share in the profits, is a solution of the difficulty which is afforded by the conditions of many foreign concessions.

Scarcity of capital justifies high profits.

Lapsing of monopoly after term of years.

Assured revenue from street lamps.

Although the inhabitants of a town are left free to purchase the gas or not as they please, it is an almost universal stipulation that the municipality shall pay for gas lamps in the streets; and thus not only is the superiority of the new light exhibited in such a way as to induce imitation, but a certain revenue is secured, which in some cases may in itself ensure a net return on the capital invested: the municipality who may have refused to guarantee interest, in effect guaranteeing a minimum revenue. It is usual to agree in advance for a certain or minimum number of street lamps; and the price may be fixed at a rate per lamp per hour, or per lamp per annum: in the latter case the average hours for lighting being specified. If the lamps are required every night from sunset to sunrise, the time can be easily calculated and agreed upon; but in some towns economy is sought by extinguishing some or all of the lamps after a certain late hour, while in other cases advantage is taken of moonlight nights to save gas after the rising of the moon. If, as is generally considered convenient in the latter event, the hours and seasons are arranged beforehand from an almanac, the town is frequently left in darkness during cloudy nights. Moreover, economy cannot be obtained proportionate to the quantity of gas so saved, for such variable hours cause more trouble to the lamplighters, while the manufacture and storage of the gas are more expensive because more irregular. A higher rate for gas so supplied may therefore be justified. It is impossible, of course, to give any standard of price for these services in foreign towns, depending as it does primarily on the cost of coal, the expenses of manufacture, and the taxation to which the undertaking is subjected; but the rates agreed upon are generally considerably in excess of what would be paid for a similar supply in England or other places where coal is cheaper, or where a large consumption of gas might be relied on with certainty, or where—as in England—the abundance of capital keeps down to a lower standard than elsewhere the rate of interest which is accepted as sufficient. The price at which gas may be sold to the public may be also agreed upon, but is generally left to the discretion of the concessionnaires within a certain limit, or with perhaps the stipulation already referred to, that the prices must be lowered when the profits reach a certain point, or that the profits, after a certain amount has been reached, shall be shared in by the town.

Price for street-lighting, how arranged.

Gas saved on moonlight nights.

Irregular lighting inconvenient.

Price of gas, how determined.

Selling price of gas agreed upon.

See page 212.

Besides agreeing upon a remunerative price for the gas thus sold

Good quality gas demanded.

to the municipality, there are several other important points for the concessionnaires. Generally, conditions are imposed in regard to the illuminating power and purity of the gas; so determining the kind or quality of coal that must be used, and the cost and trouble of manufacture. The ordinary measure of illuminating power is the number of sperm candles (each candle consuming 120 grains per hour) which gas consumed in a standard burner at the rate of 5 ft. per hour will equal. In English towns the quality of the illumination specified by the municipal authorities for street lamps, and generally defined in the Acts of Parliament by which the Gas Companies derive their powers, varies in different towns from 12 to 20 candles, 14 to 16 candles being the most usual qualities. In gas-works dependent on a foreign supply for all or part of the coal, a high standard of illuminating power renders the maintenance of a sufficient store more than usually important, because, as a certain proportion of high-quality coal is necessary for producing such gas, the supply of suitable coal must be maintained at whatever cost; while, if a lower illuminating power, and therefore coal of an ordinary quality suffice, economy may be often obtained by buying chance cargoes, by waiting to take advantage of low freights, and utilising to a greater extent during such periods local or inferior coal. One ton of Newcastle coal will yield on an average about 9,500 ft. of gas, having an illuminating power of 13 to 14 sperm candles, each consuming 120 grains per hour; leaving as residuum 13½ cwt. of coke, and 9 to 10 gallons of tar. One ton of Cannel coal (of average quality) will produce about 12,000 cubic ft. of gas, having an illuminating power—according to the quality of the coal—of from 21 to 27 sperm candles; leaving 11 cwt. of coke (not of high quality), and 17 to 20 gallons of tar. In addition, there are the other residual products of breeze and ammoniacal liquor, which are generally saleable at remunerative prices. Almost all kinds of coal deteriorate during a long voyage, especially if through the tropics. In storing coal, about 45 cubic ft. of space per ton is required; the storage space should be covered, and sufficient ventilation provided to prevent spontaneous combustion.

Illuminating power of gas.

High quality coal necessary.

Economy in coal.

Newcastle coal.

Cannel coal.

Residual product.

Storage of coal.

See, in Part II., EXPORT OF COAL.

Gas-making burdened by expenses.

Where coal, because of high freights, heavy import duties, or other burdens, is expensive, and the selling price of the gas proportionately enhanced, the new enterprise is, of course, greatly weighted in competition with existing systems of lighting. It must not be supposed that in a foreign town, where gas-lighting has

Competition with other kinds of lighting.

been previously unknown, gas of an inferior quality will suffice; for it is generally the wealthier inhabitants who first adopt the new light, and they may, presumably, have been accustomed to the best kind of lamps or candles, and will naturally expect a greater degree of brilliancy than that to which they have been accustomed.

Standard of purity for gas.

In regard to the purity of gas, freedom from sulphur and ammonia are the essential conditions, as the presence of these substances renders the gas disagreeable, unhealthy, and hurtful to furniture or pictures. In many large towns official analysts or referees are appointed, who periodically, or when called upon, examine the gas: fines or penalties being imposed on the gas company when the degree of purity is below that specified—the tendency of recent years in England having been towards increased stringency in these conditions.

Onerous conditions.

Gratuitous gas.

Fines.

Conditions, how enforced.

Impartial tribunals.

See pages 23 and 51.

Onerous conditions in other respects are sometimes imposed on concessionnaires, such as that certain public lamps shall be supplied gratuitously, or at favourably low rates; that fines shall be incurred for stoppages in the supply, or for lamps accidentally extinguished; as well as for non-fulfilment of the conditions just referred to concerning illuminating power and purity. While certain regulations in regard to all these matters are equitable and desirable, promoters of new gas undertakings have in many instances, in their eagerness to acquire concessions or monopolies, agreed to conditions which are obviously too severe, or which have been found afterwards to press unduly on the enterprise. No proper estimate can be formed of the value of a concession without a knowledge of what is or will be demanded by the authorities on these points. Not only in regard to the conditions, but in the manner of enforcing them is caution necessary. Sometimes the imposition of fines, and the settlement of questions arising out of the concessions, are left to some government or municipal official, who may be ignorant or partial. It is important that the decision, either in the first instance, or at any rate on appeal, should lie with a qualified and impartial tribunal, able and willing to enforce its decisions; and that a similar authority shall adjudicate on the claims for payment for gas supplied, for theft of gas, or on other matters, as required by the concessionnaires.

Profit from extra works.

See also page 172.

Stipulations may be made securing to the concessionnaires the monopoly of private extra works, such as those necessary for making connections to the mains, and laying of branch pipes into the houses, the supply of meters, and in some cases of house fittings. Certain necessary privileges, also, must be conferred upon the concessionnaires or gas company, such as the right of way for pipes, the right of excavating in the streets, and, with certain qualifications, the right of entering houses in which gas is consumed. In England, the Acts of Parliament by which gas-works are established authorise bye-laws for preventing misuse or theft of gas, and for protecting the apparatus and other property of the gas company. It is equally, or even more, important in countries where there is no precedent for such bye-laws that the necessary regulations shall be agreed upon beforehand, and embodied in the concession or enactments under which the gas undertaking is established.

Bye-laws.

See also page 172.

Consumption of gas.

The quantity of gas consumed in any town depends not only on the population, but on the wealth, habits, and occupations of the people. In estimating the quantity of gas which will be required, so as to decide what capacity for manufacturing and storing will be necessary, the ordinary consumption must not be considered, but the extraordinary or exceptional consumption, such as for illuminations and for times of festivals, although during such periods the ordinary consumption may be partially suspended. Moreover, as the population of a town grows, or as the demand becomes greater, more gas will be consumed; and as time is required for extending the works, they should not only be arranged at the beginning with a view to after extension, but the manufacturing capacity at any time should always be in advance of the demand.

Capacity of works, how determined.

Extension of works provided for.

See also page 175.

Consumption per head of population.

In order to establish a basis of computation for towns of different sizes, it is necessary to assume a certain rate of consumption. If the towns in Great Britain where gas is used were tabulated according to the population of each within the area supplied with gas, the extreme minimum and maximum quantities consumed per annum would—if very exceptional cases be omitted—probably be about 1,500 and 3,000 ft. per head of population. In London the consumption has (1877) attained to 4,000 ft.: there being always a tendency in capital cities to later hours and greater consumption than in provincial towns. A mean between the ordinary extremes gives about 2,200 ft. per head; but as in foreign countries where gas is first introduced the consumption is generally less than in English towns, 1,500 ft. and—as is often the case in newly-settled

Consumption less in foreign countries.

countries, where much of the population is of an inferior race—even 1,000 ft. may be taken as a more probable estimate.

Average hours for gas-lighting.

Summer and winter consumption.

Where street lamps burn all night, as in London, the minimum and maximum number of hours in summer and winter may be taken as 6 hours and 14 hours, or an average of 10 hours, though in certain climates, times of fog occasionally derange previous calculations. The average consumption in private houses, factories, and public buildings is generally estimated at 4 hours per day; and as the gas is not usually consumed after midnight, the difference between summer and winter is much greater than with public lamps. Gas-works in any town to be equal to the demand must, as already stated, be capable of producing every 24 hours the extreme winter rate of consumption. Thus, if in a town of 5,000 inhabitants 10 million cubic feet per annum be consumed, the works must be equal to supplying daily not $\frac{1}{365}$th part of this, or, say, 28,000 ft., but, if a reserve power for exceptional occasions be needed, probably double that quantity, or 56,000 ft.

Cost of gas-works.

New inventions and improvements.

The cost of foreign gas-works may be calculated in England more nearly than that of the other undertakings referred to in preceding chapters, because it depends less upon local circumstances; the apparatus and works necessary for a certain number of lights, being (subject to certain circumstances of locality) almost the same everywhere. It may be said that the progress in the art of gas-making has not equalled that of other applied sciences; and the inertness has been mainly owing to the monopoly which gas enterprises have enjoyed, and to the consequent lack of that stimulus which free competition alone provides. Notwithstanding this comparative backwardness, there have been many ingenious inventions connected with the apparatus of gas-works, and improvements in the methods of manufacture; and better and purer gas can now be obtained, with less wear and tear of plant and with a less consumption of coal, than were formerly necessary for impure gas. On the other hand, owing to the increased expense of materials and labour, the cost of gas has in some respects become greater.

Cost of foreign gas-works.

The cost of gas-works in foreign countries is, of course, greater than in England in proportion to the distance, the expenses of carrying the apparatus, the extra cost of erecting buildings, and other circumstances; the following being the principal incidents which must be taken into account in any estimate based upon precedent or fixed standards:—

Incidents of cost enumerated.

a. The cost and tenure of land for the works:
b. The nature of the soil:
c. The climate:
d. The area of the district in proportion to the number of houses:
e. The cost of building materials and labour:
f. The expenses of management:
g. The latitude, by which variations in the length of days are determined:
h. Freight, import duties, and taxes.

The above points may be elucidated as follows:—

Site for gas-works.

a. It is not always easy to obtain on suitable terms a site which will combine all the advantages desired: these being—sufficient area for the works and room for extension; a shape which will allow of a convenient and economical disposition of the buildings (great irregularity, or a shape very narrow in proportion to length, is undesirable); facility for delivering coal, and for despatching coke and other products; a low level, from which the gas can ascend to the other parts of the town; a central position, so far as the other conditions will allow, this latter being of more importance than the low level. The unwillingness of the inhabitants, especially the wealthier classes, to have the gas-works in their neighbourhood, also often limits the choice of site.

Local dislike to gas-works.

Nature of soil.

b. Upon the nature of the soil the kind and cost of the foundations will depend, points of great importance in regard to the gas-holder tanks, and—in a lesser degree—to all the other buildings. If the soil be very hard clay or rock free from fissures, a tank simply excavated and unlined may be sufficient; but in the great majority of cases the pit has to be lined with masonry, brickwork, or concrete. The use of concrete only, instead of brickwork, has not hitherto (1877) been very successful. Considerable expense is sometimes incurred in obtaining suitable puddle-clay for forming a water-tight lining. If the soil be very loose or wet, iron tanks become necessary; and to this expense has sometimes to be added the cost of pumping during the excavating and building, or of piles driven into the ground to make a sufficiently firm base for the foundations. On sites situated on the low-lying banks of a river or sea, or on very marshy land, even iron tanks cannot easily be sunk below the soil, and it becomes necessary to build the tank entirely above the ground level. The cost of the retort-settings and of the various

Gas-holder tanks.

Foundations sometimes very expensive.

buildings is also dependent to a large extent on the nature of the soil and the foundations.

Climate.

c. Extreme climates render special precautions necessary. In countries exposed to high winds, or heavy falls of snow, the gas-holders and the roofs of the buildings must be made correspondingly strong; in cold climates the gas-holders and other parts of the apparatus usually in England left open to the air, are generally entirely enclosed in buildings: pipes and other parts being also protected from frost; in hot climates, arrangements have to be made for keeping cool the gas-holders, and for extra ventilation in the various houses.

Extremes of temperature.

Area of district to be lighted.

d. The area of the district as compared with the number of houses determines the quantity of pipes necessary for a certain sale of gas; and where small out-lying districts or suburbs have to be served, especially where the number of consumers is at first small, the cost of pipes increases the capital outlay without much return in revenue. In English towns the population per mile of main ranges from 1,000 to 3,000.

Population per mile of main.

Building materials.

See also page 70.

e. The cost of building-materials varies very much in different countries; and in many towns where gas-works have been established by foreign capitalists there is neither brick, stone, nor timber available, and these materials, or ironwork as a more convenient substitute, have at considerable extra expense to be imported. The difficulty of obtaining suitable workmen has also often to be encountered.

Expenses of management.

f. The expenses of management in foreign gas-works are often very great, especially where skilled superintendents have to be sent from a distance, and such charges tell heavily on a small revenue.

Latitude determines length of daylight.

g. In the latitudes near the equator the lengths of days approximate more nearly in winter and summer than in countries outside the tropics, and this circumstance tends to economy in the expenditure of capital. For as it is necessary in constructing gas-works to provide for the maximum consumption of the longest nights, much of the manufacturing and storage capacity of works situated in latitudes where the length of days varies much with the seasons, is idle and profitless during the summer.

Freight and insurance.

h. Freight and insurance add considerably to the cost of apparatus imported; and, for towns not situated on the coast or on navigable rivers, the cost of inland carriage, especially if the coal has also to be imported, sometimes forbids altogether the profitable erection of gas-works. To these unavoidable expenses are often added high import duties on iron and machinery: these duties being often imposed, not merely for purposes of revenue, but with the fallacious idea of protecting and benefiting home industries. In such cases the undertaking is greatly weighted in competition with other and previously existing methods of lighting, and the cost of gas to the inhabitants is of course enhanced. The privilege of importing material free of duty is often sought by concessionnaires, but except in the case of capital cities is not granted so readily for gas-works as for such undertakings as railways and harbours, which may be considered as of more national importance.

Import duties.

See also page 2.

Immunity from duty allowed.

See page 26.

It has been seen from the foregoing pages that any estimate of the cost of gas-works in a foreign country depends upon many variable circumstances, and therefore that even an approximate statement of cost must in regard to these circumstances be based upon certain conjectural assumptions. The capital outlay in connection with gas-works, including mains, ranges in England from 10s. to 16s. per 1,000 ft. of gas-manufacturing capacity per annum; though in large cities like London and Paris, the rate sometimes rises to 20s. Or, to take another measure of value, the cost of gas-works ranges from £4 to £7 per ton per annum of coal-carbonising capacity, or, in the exceptional cases above referred to, may be as much as £9. The capital outlay expressed by the higher of these rates includes considerable expenses in connection with Parliamentary contests, compensations, and the somewhat wasteful expenditure in construction at a time when the science of gas manufacture was not well understood.

Variable cost of gas-works.

Approximate cost of gas-works.

The quantity of gas which can be discharged per hour through a pipe of a certain diameter depends upon the pressure of the gas and upon the length of the mains. As the friction increases with the length, the diameter of the pipe must be increased where the mains extend far; and to afford a basis for an approximate estimate, it is necessary to assume a certain pressure, which, as an ordinary average, may be taken as equal to that of a column of water 1½ in. high.

Passage of gas through pipes.

See PIPES, *in Part II.*

Ordinary street lamp-pillars, complete with lamps and pipes, cost from £2 10s. each upwards; those suitable for the principal streets of a city costing £5; large pillars with groups of lamps from £12 to £50 each. Each street lamp with one burner consumes from

Cost of lamp-pillars.

4 to 5 cubic ft. per hour, and the same consumption may be assumed for private burners.

Cost of works per head of population.

In England the cost of gas-works, including mains, averages from 15s. to 25s. per head of population, the lower rate being for towns of very small size. In the case of very large cities, where works of extraordinary magnitude are constructed, the higher figure is sometimes much exceeded. Gas apparatus on a small scale, for supplying mansions, factories, or villages, is made in England, especially for export; the capacity of such apparatus being stated according to the number of lights which it can supply for a certain number of hours per day; but the proportions which the storage bears to the manufacturing capacity can be arranged to suit particular cases. A complete apparatus for supplying 200 burners for four hours daily, and including necessary fire-bricks, costs from £200 to £250, and weighs about twelve tons. An apparatus for supplying double the above quantity would cost about £400, the price per unit of supply gradually diminishing as the size increases. For any number of lights beyond 500 it is seldom expedient to export an apparatus, unless it has been designed on purpose to meet the necessities of the particular case.

Apparatus for making oil-gas.

See also page 225.

Special apparatus for manufacturing gas from oils, petroleum, &c. is also made on a small scale, the prices ranging from £50 for an apparatus sufficient for 50 lights, to £1,000 for one sufficient for 2,000 lights: the weight for shipment ranging from 2 to 30 tons.

Profits depend on good management.

The profits of any gas-works obviously depend not only upon the capital outlay, the cost of coals, and the selling price of the gas and residual products, but upon the skill in management; though this fact has not had its logical outcome in those towns—numerous in England—where the advantages of a monopoly, and the absence of an authoritative limit to price, allow the gas company to recoup themselves by high charges for an unnecessarily high cost of manufacture. The current expenditure depends primarily upon the skill with which the works have been designed in the first instance, so as to allow the various processes to be carried on with the minimum of labour. Simplicity should be studied in the design of the buildings; and, both in the arrangement of the apparatus and the order of procedure, economy will be attained by conforming as far as possible to the habits and capabilities of the native workmen.

Skill in design necessary.

Economy in manufacture.

Cost of gas-making. **Selling price of gas.**

In England, the cost of manufacture, distribution, management, and maintenance of the works, exclusive of the cost of coal and of interest on the capital invested, and without taking credit for the revenue from coke, tar, and other residual products, ranges from 1s. 6d. to 2s. per 1,000 cubic ft. The cost of the gas itself depends of course principally upon the cost of coal. In England, the selling price of gas varies from 2s. 6d. to 7s. per 1,000 cubic ft., according to locality and the current price of coal; and these rates generally allow ample profit to the makers. In foreign gas-works established by English enterprise and belonging to English capitalists, the prices range from 5s. to 20s. per 1,000 ft. In cases where the higher of these rates are in force, not only has all the apparatus generally been supplied from England, but the whole of the coal has to be transported thence at very great cost.

Value of residual products.

The value of the residual products varies in different localities, mainly according to the demand for, and the current price of, fuel; and, in some cases, the revenue from such sales expresses very nearly the net profits of the entire undertaking. Sometimes in places where there is no sale for tar, the retort furnaces have been arranged so that the tar can be utilised as fuel.

Waste of gas.

To arrive at the profits of gas-works—after the cost of works, coal, and manufacture has been reckoned—the waste must also be taken into account. In English gas-works, the amount of gas unaccounted for varies from 8 to 15 per cent. of the total quantity manufactured; and it will be seen that the difference which these limits express—and which represents degrees of skill in management—is in itself sufficient to pay a fair interest on capital.

Information for designing new works. **Particulars classified.**

For designing the works and apparatus necessary for supplying a town with gas, the following information is required; and, the scheme having been prepared, the cost of establishing the works and making the gas can be ascertained. On the basis of such estimates of cost, and with the following information before them, contractors or capitalists can form an opinion as to the probable profits of the enterprise.

Plan of town.

1. A plan of the town, with the names of the streets and the lines of the pipes marked upon it, with a key or explanatory list describing which are the principal streets and public buildings, and the proposed site for the gas-works. The different levels of the town should be marked with reference to some datum.

Population. **Habits of people.** **Methods of lighting.**

2. The number of the inhabitants; the past and probable future rate of increase in the population; a classified list of the number, kind, and value of the houses; the avocations and customs of the people; the existing system of lighting in the streets and houses and the cost; and any other information by which the probable consumption of the gas may be estimated.

3. The experience of gas-works in neighbouring towns, or in other places where the circumstances are similar.

Kind of coal obtainable. **Transport.**

4. If coal exists in the country, its suitability for gas-making should be minutely described, samples furnished, its cost at the mines stated, and the means and cost of transport to the gas-works described; together with the means and cost of landing imported coal, and conveying it to the gas-works.

Dues and taxes.

5. The harbour or town dues that exist, or which may have to be paid; the import duty, taxes, or imposts to which the apparatus, coal, or the revenue or profit may be liable.

Cost of land. **Water supply.** *See Chapter IX.*

6. The cost of land on which to build the works, and the terms or tenure on which the land can be held, and whether there is any likelihood of objection from the inhabitants on the score of nuisance. The nature of the water supply and its cost.

Nature of soil for foundations.

7. Precise information as to the nature of the ground on which the works are to be built—whether rock, sand, or clay; whether firm or yielding, wet or dry; the depth at which water is reached, this being ascertainable with certainty either by trial pits or probings.

Building materials. **Kind of street paving.** **Laying of pipes.**

8. The cost of building materials, including those for roof covering; the kind of workmen obtainable, and their rate of wages; the quality and cost of clay for puddling the gas-holder tanks, or lime for purifying the gas; also whether suitable stone or brick buildings can be erected at moderate cost, or whether it will be better to import bricks or iron framework for buildings. The materials with which the streets are made and paved should be described, together with the drains or water pipes in the streets, and the depth at which water would be met in trenching; whether canals or streams will have to be crossed by the mains, and any other information which may affect the method and cost of laying gas pipes.

Value of fuel. **Probable demand for coke.**

9. The kind of fuel in use in the town for domestic or manufacturing purposes, its cost, its abundance, or otherwise, and any other information by which the probable demand for and the selling value of coke may be estimated; so, also, any outlet which may be reckoned on for the sale of the other residual products.

Materials for gas-making, oil, resin, naphtha.

10. If coal for gas-making cannot be brought to the site at a sufficiently moderate price, any other available materials for gas-making—such as resin, resinous wood, naphtha, oil, or petroleum—should be described, together with the cost, the sources of supply, and the cost of transport.

Climate.

See also page 70.

11. The nature of the climate should be described, not only for its effect on labour and materials, but because, as already mentioned, the designs for the buildings and apparatus for a gas factory are in many ways determined by the information on this point.

Terms of concession.

See pages 18 to 33.

12. The terms of the concession granted by the municipality, or which may be reasonably expected, should be stated fully, with special reference to the following points: the nature of the monopoly, the length of term, the subsidy or guarantee or facilities which are to be granted, and the obligations which are to be enforced on the concessionnaires.

Estimated consumption of gas.

13. The estimated consumption of gas, and the *data* on which the calculations of revenue have been based: the engagements which have been made for supplying lamps in the public streets, and for gas in private or public buildings: and the prices and terms of such engagements.

Rate of exchange.

See, in Part II., BRITISH STERLING.

14. The fluctuations in the rate of exchange which—as judged from the experience in the past—are likely to occur. If coal has to be procured from a foreign country at its intrinsic value, while the payments for gas are made in depreciated currency, the revenue, if measured in British sterling, will be much diminished.

[*See also* CONCESSIONS: WATERWORKS: *and, in* PART II., THE ESTABLISHMENT OF FACTORIES: COAL: PIPES: IRON ROOFS AND BUILDINGS.]

CHAPTER XII.

TOWN TRAMWAYS. COUNTRY TRAMWAYS.

Tramroads antecedent to railways.

Stone trams.

Paved roads in Italy.

Stone tramroads in London.

On bridges.
See page 126.

On steep ascents.

Although iron tramroads, the precursors of railways, existed in the mining districts of England in the last century, their introduction into towns for passenger traffic took place long after the date of railways. Stone trams have been constructed even in early times for heavy traffic in cities, not so much because of the easy traction which they allowed, but because unpaved roads were too yielding for heavily-loaded waggons: the old method of meeting this difficulty by using broad wheels having many inconveniences. Stone trams on highways are common in some districts of Italy, and these may be considered to be only a modern adaptation of the famous paved roads constructed by the ancient Romans. In London, before 1830, a stone tramway was laid from the City to the docks for the passage of waggons carrying heavy merchandise, and this stone track remained till it was taken up to make room for an iron tramway. The application of granite paving to city streets removes one of the reasons for stone trams—viz. want of hardness in the road material—and although the superiority of the stone trams for easy traction still remains, yet as these can only be applied with advantage where the traffic is marshalled into line, they are seldom of use in crowded streets. On London Bridge and other of the bridges over the Thames, where the heavy slow traffic is separated from the light traffic, stone trams are used with advantage; and on some of the steep gradients of suburban highways stone trams of a similar kind are constructed on the left hand, or ascending track. Again, in many of the narrower streets of London, Paris, and other important cities where the traffic is marshalled into line—especially, for instance, in the streets only wide enough for one line of vehicles—easy traction and a good foot-hold for the horses are maintained by paving the wheel-track with smooth blocks, and the horse-way with granite setts. Sometimes—as on London Bridge—side rubbing-plates of iron, attached to the curb, are combined with the stone tram.

Stone trams in city streets.

On London Bridge.

The modern system of asphalte paving, affording as it does a smooth surface free from the numerous jointings which stone paving requires, allows great ease of traction; and asphalte, if it were universally adopted in a city, might go far to obviate the need for iron tramways. But nowhere is asphalte paving continuous over long routes; and it has the great disadvantage in wet or muddy weather of affording a bad foot-hold—a circumstance which, while very trying to the horses even on level roads, entirely forbids its use on any but easy gradients. If, however, asphalte paving were universal in a city, there would be less mud, this being produced chiefly on the macadam and granite paved roads.

Asphalte paving allows easy traction.

Asphalte sometimes slippery.

Iron tramways for conveying passengers in towns were in operation in the United States as early as 1840, but their general introduction into New York, and other of the principal cities, was met by an opposition like that afterwards experienced in London. The general adoption of tramways in America may be said to have taken place twelve or fifteen years earlier than in England, and this arose from a variety of causes. The want of convenient conveyances for passengers was much greater in American cities than in London, for the service of omnibuses and cabs was less efficient, while the inconvenience, so loudly proclaimed then and since by the opponents of tramways everywhere, that the iron rails would spoil the roads and obstruct the traffic, had not much weight in American cities, where the streets were badly paved. The safety of the public, too, was there less considered, free passage being—for example—allowed to trains on unfenced railroads crossing city streets. In English cities, on the other hand, where the street paving is better, and where strict regulations in regard to traffic are enforced, the promoters of tramways had a harder opposition to encounter, as is evidenced by the more onerous conditions in regard to the rail-track with which they have to comply. Undoubtedly, also, the greater regard for vested interests which prevails in England, and the stronger prejudice against everything new, did much to protract the period of opposition there.

Town tramways in America.

Earlier than in England.

Causes of delay.

Vested interests in England.

See page 3.

First English tramways in Birkenhead.

The first tramways in England were established at Birkenhead in 1860 by an American engineer, who in the same year obtained permission to lay experimental tramways in London; but there his lines were not successful, principally because of the ill-chosen projecting rails of American pattern, which obstructed the general traffic in the streets. The tramways were condemned by the authorities and removed in 1861, and this unfortunate and abortive inauguration of the new system of locomotion prejudiced the public mind against tramways, and was the principal cause of postponing their introduction to the metropolis for the next eight years. About 1865 a renewed attempt was made to introduce tramways into London, and during the four following years there was an animated warfare between the promoters of the tramways and their opponents. The opposition came chiefly from the proprietors of omnibuses and from the owners of the property along the routes, who were led to believe that the tramways would prove a nuisance; and notwithstanding that the previous faulty method of laying the track was disclaimed, the owners of private carriages opposed on the supposition that the rails would injure their vehicles. Moreover, the space occupied by the line was spoken of as if it were to be permanently monopolised by the cars. At last, however, the public mind became so thoroughly convinced of the advantages of properly constructed tramways, that, in spite of the most strenuous opposition both in and out of Parliament, the first metropolitan lines were sanctioned in 1869. Since that time, tramways have been established in different parts of London, and by December, 1877, about fifty miles of street-way were occupied (principally by double lines) within the metropolitan area. Concurrently with the construction of lines in London, tramways have been established in most of the larger English towns. Tramways have been constructed in most of the principal cities of Europe and South America, where the circumstances are favourable. In Paris the first tramways of any importance were completed only in 1875, but have since been greatly extended.

Experimental line in London.

Condemned and removed.

Opposition to tramways in London.

Allegations against tramways.

Opposition overcome.

Tramways established in England.

In Europe and South America.

In Paris.

Tramways profitable.

Tramways have opened out a new field for engineering enterprise, and, if established on proper conditions, afford a safe and remunerative return for capital. If judged by the price that investors will pay for shares producing a certain amount of interest, tramway undertakings do not in England differ much from railways, and it may therefore be assumed that the advantages and disadvnatages of the two undertakings nearly balance each other. When first com-

Compared with railways.

menced, the works of a tramway are much sooner remunerative than are those of a railway, and there is not so much room for uncertainty in the amount of expenditure either for works or for purchase of property. Moreover, an increasing traffic does not augment so largely the proportionate expenditure for maintenance as in railways, because the wear upon the permanent-way and street paving is determined not by the number of tram-cars which pass, but by ordinary vehicles; and the greater the car traffic the greater will be the share of advantage which the tramway proprietors will obtain from an expenditure for maintenance which must in any case be incurred. On the other hand, railway shares have a speculative value arising from the expectation of increased profits in the distant future, as is clearly evidenced by the prices paid for shares in non-dividend-paying lines. These potential profits are limited in the case of tramways to the term of the concession (in English towns generally only 21 years); for it can hardly be doubted that where a tramway undertaking pays dividends high enough to give a more than par value to the shares, the public, as represented by the municipal authorities, will, when the time for renewing the lease arrives, claim to participate in the profits either by a reduction in the tariff of fares or by an increased rent for the use of the road. If, however, the line has paid no more than a nominal rate of dividend, the proprietors will be left to work it as before. Such conditions give a one-sided aspect to the transaction as between the town and tramway proprietors, which doubtless does much to limit the value of the investment in the estimation of capitalists. Very large dividends have been earned on some foreign tramways, and the shares have attained a proportionately high price, these cases mostly arising where favourable terms had been granted by the authorities at a time when the value of such enterprises was unknown.

Tramways less uncertain.

Growth of traffic.

Potential profits of railways.

See page 66.

Limited term of tramway leases.

Permanently high profits forbidden.

The conditions upon which tramway concessions are granted vary in different countries, but generally only in detail, as there are certain primary points—principally the letting by lease and the obligation in regard to the street-paving—which are common to all cases. Although tramways have been established in all the principal cities of Europe, the only two countries where precise conditions and elaborate rules of procedure have 1877) been established, are England and France. In the construction of the earlier French tramways, the indispensable and only condition for the granting of a concession was the consent of the town authorities; but in France, as

Tramway concessions.

General conditions.

Precise conditions in England and France.

well as in England, the principle has since become firmly established that the imperial or national government shall alone have power to grant concessions, although the support or opposition of the municipality, or road authorities, has great weight in influencing the decision of Parliament, or of the Minister of Public Works, as the case may be.

French tramways.

German tramways.

In Germany, by a decision of the Government in 1872, the granting of concessions for tramways was left in the hands of the local authorities. Permission has, in the first instance, to be obtained from the police (who in Germany have many functions not usual in England); but separate arrangements have afterwards to be made with the municipality in regard to interference with the streets.

Italian tramways.

In Italy, concessions for tramways in towns are granted by the municipal authorities: but for tramways passing outside the towns or on the country roads (and there is a disposition to construct such lines in Italy), permission has to be obtained from the provincial administration, the approval of the national Government being afterwards necessary, an Act of Parliament being sometimes—though rarely—required for this purpose.

Spanish tramways.

In Spain, concessions have been granted and tramways successfully established in different towns by permission of the local authorities (in Madrid with the Government sanction). By a royal decree of November, 1877, it was enacted that for the future, tramway concessions are to be granted only by auction to the highest bidder.

American tramways.

In the United States, Congress does not interfere, and concessions or charters are granted by the State Legislatures to joint-stock companies in the various towns, the municipal authorities protecting the public interests in regard to paving and other matters, by the insertion of suitable clauses and bye-laws in the authorising acts.

English tramways.

In England, an Act of Parliament is necessary for the construction of tramways, but in many cases they are authorised by Provisional Orders of the Board of Trade, without any direct application by the promoters to Parliament; and when several new tramways have been so authorised in the same year, they are all included in one confirmatory Act. But this method of procedure, which is much simpler and cheaper than that by a separate private Bill, is only permitted after the local or road authorities have given their consent.

Provisional Orders of Board of Trade.

See page 9.

Advantages afforded by tramways.

The advantages which a tramway offers to the public are,—easier and more comfortable travelling, a more regular service, and lower fares, than omnibuses afford; and as undoubtedly the tramway does to some extent interfere with other traffic, the real justification for such lines is that the accommodation they afford to the majority of the inhabitants far outweighs the inconvenience to the minority. While, however, these benefits justify the establishment of tramways for passenger traffic, there has been much misapprehension in regard to their use for conveying goods; engineers, as well as promoters, having in many cases failed to appreciate the very different conditions which such service, to be successful, demands. In most of the authorising Acts of Parliament for tramways in England, rates of toll for parcels and merchandise are inserted, but in some of these cases the right to carry heavy goods or minerals is made subject to the permission of the local authorities. The profitable conveyance of merchandise and parcels for short distances in towns, generally involves the distribution and delivery of the packages at particular places, and it is evident that tram-cars, with flanged wheels which must keep to one route and may not obstruct the streets by other than momentary stoppages, cannot compete with ordinary distributing carts; and although in exceptional cases, such as the conveying of goods from a railway-station to one particular warehouse or market, or from a harbour to a custom-house, or from a manufactory to a port, tramway delivery might even, for short distances, be performed with advantage, if the merchandise be in sufficient and regular quantities, no miscellaneous carriers' duty could be undertaken. When, however, the distance exceeds eight or ten miles, the cheaper haulage which a tramway allows—especially if economy be further obtained by the use of steam-cars—might justify such an undertaking, and repay a second handling of the goods and the cost of final distribution from the terminus. The circumstances by which any such project should be determined are, however, so different to those involved in a town tramway for passengers, that a scheme for combining the two services, involving, as it might do, the risk of failure in both, should be propounded only after careful consideration. The use of a passenger line for supplementary work at night, such as the conveying of road-mending material, or town refuse, is an independent question, and one which concerns the municipal authorities rather than the proprietors of the tramway.

Disadvantages.

Tramways for goods traffic.

Town tramways seldom suitable for goods traffic.

Exceptional cases.

Tramways in the country.

See page 258.

Municipal night-service.

See page 256.

The great majority of tramways are constructed and owned by

Tramway companies.

joint-stock companies, and it is only rarely that the municipal authorities either construct or own a line. In some cases, *e.g.* at Sheffield, Manchester, and Bristol—other towns also seeking (1877) similar powers—the tramway is made by the Corporation and leased to a company at a yearly rental. In Glasgow, the Corporation constructed the tramway and also maintains it, the company paying to the Corporation interest on the actual capital expenditure, and an agreed sum annually for the renewals and repairs; though if this annual sum proves more than sufficient for the purpose in view, the balance is returned or credited to the company. The reasons put forward for such methods are those which are adduced in favour of a municipality undertaking water-works or gas-works, which are by their nature monopolies, involving disturbance of the surface of the public streets. Under the terms of English tramway concessions hitherto granted, it is probable that many of the lines constructed by private companies will hereafter become the property of the public by purchase; and in the case either of construction or purchase by public authorities, the necessary money may be raised by loan in the manner prescribed for local public works generally. But while the law in England allows municipal bodies to construct or acquire tramways, it has as yet (1877) forbidden them to work the lines, Parliament in this matter restraining the modern tendency of town authorities to commercial enterprise which has led them to construct and carry on water and gas works. By whomsoever the tramway may be made, the Board of Trade exercises, as in the case of railways, considerable power of supervision both in regard to the mode of construction and the working of the line. In France a similar power is exercised by the Minister of Public Works, who has every detail submitted to him for approval.

Tramways made by town corporations.

Justification for municipal undertakings.

See pages 166 & 209.

Purchase of lines by town authorities.

Municipality may own but not work tramways.

Board of Trade supervision.

See pages 4 & 58.

Concessions for tramways are generally given for terms of years. In England the usual stipulation in the authorising or confirmatory Acts of Parliament is, that at the expiration of a certain period (generally 21 years) the local authorities shall have the power to require the removal of the tramway, or to exercise the option of purchasing it from the proprietors, with all its plant and appurtenances, at such a value as shall be determined by some impartial tribunal, or by an arbitrator to be nominated by the Board of Trade; such an assessment of value, however, to include no compensation whatever for loss of prospective profit, or for the compulsory nature of the transfer, or for anything beyond the mere

Concessions for terms of years.

Option of removal or purchase.

property itself. After 21 years of working it is to be presumed that the pecuniary success or failure of the enterprise will be settled. If successful, the authorities will exercise their option and purchase the tramway, leasing it again to a company on conditions equivalent to an increased rental. In many cases there will probably be no actual purchase or transfer, but the terms of maintenance, tariffs of tolls, and other conditions will be revised or altered in a way more or less favourable than before to the public or the proprietors, according as the working of the tramway has been profitable or otherwise in the past.

Renewal of lease on altered terms.

Terms of lease in France.

In France the term allowed to the earlier companies was 30 years; in other cases terms even up to 60 years were granted, but by the more recent concessions a term of 40 years seems to have become established in France as a standard. In most of the French concessions the tramway becomes at the end of the term the absolute property of the public authorities without any payment whatever, the rolling-stock being purchasable at a valuation; such conditions (which in France are those usual, though with a longer term, for railways) requiring on the part of the proprietors the establishment of a sinking fund before any dividend can properly be paid.

See pages 13 & 37.

In Germany.

In Germany, periods of from 10 to 30 years have been granted, (25 and 30 years being the most usual periods), generally on conditions which will allow of a renewal on similar terms, if experience show nothing detrimental to the public interests.

In Italy.

In Italy the concessions for town tramways have been generally for periods of from 30 to 40 years, the tramway and its equipment becoming the property of the town at the end of the term, the conditions in this, as in several other minor matters, resembling those usual in France.

In America.

In the United States, the charters generally declare the conditions under which the proprietors of the tramway may be called upon to remove it, but without specifying any particular time.

Rent payable, or road maintenance required.

See page 33.

In granting the use of the public roads to a tramway company, rent is generally demanded by the municipality in return, either in the shape of money or a share in the profits, or in obligations of road maintenance, or in the deferred payment which a free surrender of the property at the end of the term implies. Conditions of this sort have become more onerous than in the earlier concessions. In some foreign tramway concessions an annual rent in money, in addition to the maintenance of the road, is demanded.

Monopoly of track withheld.

The absolute monopoly of the tramway is withheld in some concessions, and any person may, under certain regulations, and on payment of certain tolls to the tramway proprietors (either specified in the concession or sanctioned afterwards by authority), run cars upon the track. In this respect the precedent of railway legislation in England is followed, where the same nominal conditions are established. For it was not considered at all certain, when railways were first introduced, that the owners of the roads would alone own engines and carriages, but would—like the proprietors of canals—take toll from any carriers who chose to claim the right of way. But with tramways, as with railways, these nominal conditions are lost sight of, and no independent carriers would be able successfully to compete with the owners of the road; although Parliament would probably grant running-powers to the proprietors of adjacent lines, if shown to be for the convenience of the public. In Berlin, where there are numerous tramway companies, provision for such running-powers is in certain cases made in the concessions.

Running-powers.

See also page 71.

Expediency of tramways—how determined.

There are certain main points by which the expediency of introducing tramways into a town may be determined, and the probabilities of profit measured. They are:—

Local circumstances enumerated.

1. The Population of the town and the situation of the suburbs.
2. The Width and degree of regularity of the streets.
3. The Gradients.
4. The kind of Rail-track and road-paving.
5. The Cars.
6. The Hauling of the cars either by Horses or Steam traction.
7. Working expenses.
8. The Tariff of fares.
9. Minor privileges, obligations, and bye-laws.

Although all the above points are subjects of discussion when tramways are proposed, points 2 and 4 are those which mainly concern the town authorities, and on which controversy principally arises. The rail-track and road-paving chiefly determine the cost of a tramway, and all the points together the profits of working. These several subjects may be elucidated as follows:—

Population.

1. *The Population of the town and the situation of the suburbs.*—As the profits depend upon the proportion which the gross earnings bear both to the capital and to the working expenses, it is obvious that a large busy population will be the most remunerative. A line

upon which four cars per hour pass will have cost as much as if twenty cars per hour were running, and the working expenses for the smaller number are in proportion heavier; therefore, the capital and the current outlay obtain the best return—as expressed by the mileage earnings—from a population that affords a constant succession of passengers along the whole route. Suburban or "omnibus" traffic of this sort is more profitable than that on a line which connects two towns, between which there is little intermediary traffic; for in the latter the mileage will probably be long in proportion to the number of persons carried. On the other hand, in a town compactly built, with few or unimportant suburbs, or with only short distances to traverse, there is not much inducement to ride, and, if there be much traffic in the streets, there is yet the maximum obstruction to the cars. There are few towns in England having less than 40,000 inhabitants (except at places of pleasure resort), where tramways would be remunerative; but with regard to the likelihood of profit much depends upon the area covered, and upon the habits and occupations of the people. In some foreign cities with an enervating climate which indisposes people to walk, a very large proportion of the people will pay to ride.

Busy traffic most remunerative.

Suburban traffic.

Tramways seldom profitable in small towns.

Influence of climate.

2. *The Width and regularity of the streets.*—The establishment of tramways is often opposed on the plea that the streets will be obstructed by the cars, which cannot leave the track. The crowded condition of the streets in the centre of a city forbids the construction of tramways in those very cases where additional means of conveyance would be specially useful; and in such places as the City of London, where through-traffic is much impeded, the evil will probably so increase as sooner or later to demand a remedy. The system adopted in New York of overhead, or, as they are called, "elevated" railroads, is by some advocated as a suitable means of relieving crowded streets, and it is said that the lines so constructed there have been worked with advantage to the public and profit to the proprietors. There would, however, be great opposition to such a system in London, and the necessity would have to be very obvious before the erection of columns, brackets, or other necessary supports in the public streets would be permitted. But although in the centre of a crowded city like London, tramways cannot with propriety be constructed, experience has shown that in any but a few extreme cases, tram-cars assist, rather than obstruct, free circulation, because they keep the traffic in line. Straight wide streets are obviously the best

Width of streets.

43.

Overhead railroads.

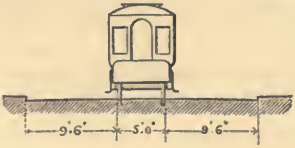
Tramways assist in marshalling traffic.

for tramways, as not only is there then no fear of their causing obstruction, but there is the less necessity for ordinary vehicles passing upon the tramway track. The greatest inconvenience is felt at the terminus of a tramway, where the cars must necessarily be detained while the horses are changed from one end of the car to the other, though to reduce the time so occupied, the plan has been tried of pivoting the car upon its under-frame, so that the horses, without being detached, turn the car round while the wheels remain stationary. This plan however is not satisfactory. But to prevent any stoppage of the roadway, the line may be made to end in a side street, or a continuous or circular tramway without any terminus may be constructed, or—especially in the case of long steam-cars—the turning may be effected on a triangle track.

Official rules as to width of streets.

See also page 190.

In England, according to the usual regulations, tramways are only permitted in those streets where a space of 9 ft. 6 in. is left between the foot-path and the nearest rail. Assuming that the extreme width outside the rails for a standard-gauge line is 5 ft., then a width of 24 ft. between the foot-paths is necessary for a single line, and for a double line having a mid-space (*entre-voie*) of 4 ft. between the up and down tracks, a width of 33 ft. is necessary. The maximum width of a tram-car is 7 ft., and as the car thus projects 12 in. outside the rail, a clear width of 8 ft. 6 in. is left for vehicles passing or standing between the rail-track and the foot-path. Opposition to tramways has even been based upon the alleged necessity of allowing carts to back up to the foot-path when unloading; which of course would involve a space greater than that necessary for carts standing parallel to the road. The width of vehicles varies generally from 5 ft. to 7 ft.; and 8 ft. may be accepted as a maximum.



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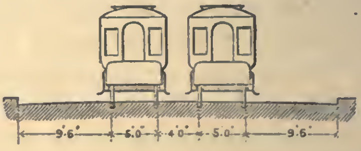


45.

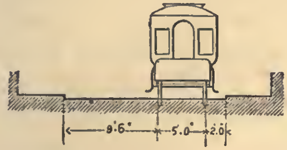
Rules in France.

In France the usual regulations allow single-line tramways only in streets 7.50 *mètres* (24 ft. 7 in.) wide, and double line in streets 9.80 *mètres* (32 ft. 2 in.) Tramways have, however, in various countries been constructed in streets narrower than those just described, and in England and France, also, exceptions are occasionally allowed to the standard conditions.

Rules sometimes relaxed.

Rails sometimes laid close to footpath.

When a street is narrow for a short distance only, and where the roadway cannot conveniently be altered to the desired width, permission is sometimes given for the rails to be laid for a limited distance near to the footway; the granting of such an indulgence generally depending on the wishes and influence of the householders or traders in that portion of the route which will be affected. As, however, in any case it is necessary that sufficient space for ordinary vehicles should be left on one side or the other, the tramway is, in streets less than 22 ft. wide, laid at one side instead of in the middle of the street, where each car as it passed would sweep the whole street. Thus, sometimes, where houses along the route are few, and where the inhabitants or authorities consent, a single-line tramway may be laid for a considerable distance with only a space of 18 in. or 24 in. between the outer rail and the foot-path. Thus again, where there is a double track, the two lines may be laid on one side of the street. But in the case of such double lines it is necessary that there shall be frequent crossing points, so that the cars on the side next the foot-path may cross over to the other line when the track is obstructed by vehicles standing by the footpath. As the space between the rail and foot-path is required mainly to allow ordinary vehicles to halt in front of a house or shop, there is not the same need for the side space along suburban roads where there are no houses or shops; and in such cases, especially if the establishment of a tramway is popular, the stringency of the ordinary rules may be relaxed.



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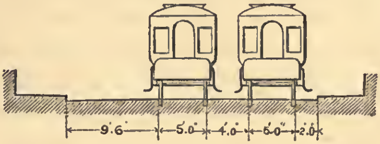


47.

Crossing-places necessary.

Suburban roads.

Loop system of working.

On a single track with passing-places, great delay and inconvenience arise in the working, and to avoid these, it is a usual plan, where streets are too narrow for a double track, but where parallel streets are available, to work on what is known as the loop system, the cars running in a perpetual circle, one street being used for the up line, and the other for the down line, the direction of the cars being sometimes indicated on the lamp-posts. Unless, however, the two tracks are near together, and easily reached by cross streets, there is a great loss of local traffic, as a line available only in one direction is apt to be neglected in favour of ordinary omnibuses, which are not so restricted. A loop, therefore, should be made as short as possible, the double line being resumed wherever the width of street allows it.

Gauges of tramways.

See Railway Gauges, *page 57.*

Various gauges of width between the rails have been tried, but although a few tramways have been constructed as narrow as 3 ft. 6 in. and 4 ft., the standard gauge of 4 ft. 8½ in., or some close approximation to it, is generally adopted; from 4 ft. 6 in. to 5 ft. 3 in. being limits which include the great majority of town tramways in Europe and America. Two horses cannot run abreast between rails much closer than the standard gauge without treading on the rails, which would cause them to slip; and although one-horse cars are frequently used, it is inexpedient to construct a track limited to such cars. The only advantage afforded by a narrow gauge is in the easier transit over curves; and in towns where the streets are narrow and sharp curves numerous, narrow-gauge lines may occasionally be adopted with advantage. It is, however, only in extreme cases that a narrow gauge can be justified, for by a suitable construction of wheels or the use of a short wheel-base, sharp curves can be passed even on the standard gauge. As the obstruction to ordinary traffic depends not on the width between the rails, but on the width of car, it is the body of the car that must be reduced if any reduction in the area of road occupied is to be effected; but the width of the cars is determined by the space necessary for passengers, and this cannot, without a great sacrifice of convenience, be made less than 6 ft. 6 in. A gauge wider than 4 ft. 8½ in., though unnecessary for the cars, is more convenient if ordinary vehicles are to use the road; and in some of the tramways of the United States, where the track is intended for general use, a wide rail with a projecting shoulder is laid with 5 ft. 2 in. gauge inside the projection. In Ireland the Irish railway standard gauge of 5 ft. 3 in. has been adopted for the tramways. In Liverpool, on an ordinary railway line laid through the docks for goods traffic (the rails being level with the ground), omnibuses with unflanged wheels run regularly; and the plan has even been tried on the Continent, of changing the wheels of the cars during each journey, when they arrive at or leave the rail-track.

Standard gauge preferable.

Narrow gauge.

See page 239.

Wide gauge.

Irish gauge.

Tramway in Liverpool.

Economy in width is obtained sometimes by reducing the space (*entre-voie*) between the up and down lines; but the saving so obtainable is very small. As each car projects from 10 in. to 12 in.

Mid-space between the rails narrowed.

beyond the rail a space of 2 ft. is absolutely necessary; and 4 ft. or 4 ft. 6 in. is usually given; but the space is often reduced to 3 ft. 6 in., or even (for a few yards at special points) to 3 ft.

Car wheels without flanges.

When the sanction of the road authorities to a tramway is withheld because of the narrowness of the streets, which might be blocked by tram-cars unable to move from the track, the difficulty may be partially met by constructing the wheels of the tram-car without flanges, so that they run only upon the rail and not in the groove of the rail; the car being kept upon the track by a small flanged guiding-wheel in front of the ordinary wheels either on one or both sides of the car. When it is desired to leave the track, the driver can do so by raising the guiding-wheel from the rail-groove by a lever; the car having then all the liberty of an ordinary omnibus. This plan, which is in operation on a portion of the tramway lines in Hamburgh and Copenhagen, resembles in some degree the system at Liverpool; but has the obvious disadvantage that the weight of the loaded car must be determined by what the horses can draw when off the track; although, of course, there remains in favour of the horses for the greater distance the ease of traction on the rails.

Guiding-wheels.

Curves.

As a tramway must follow the existing lines of streets, curves are unavoidable, especially in old towns; the more difficult cases, however, being those where the track passes from one street to another at right angles; but wherever the space allows it the radius of the curve should not be less than 150 ft. But though in curved streets, or at passing-places, such a radius is generally obtainable, there are cases where the track is so continued from one street to another that sharper curves are unavoidable. At such places a radius of from 80 ft. to 100 ft. is very frequent, and occasionally 50 ft., or even in some rare cases, 35 ft. is all that can be obtained. Although tram-cars can, as already stated, be pulled round sharp curves, they undergo a severe strain, and the track at such places needs frequent repairs. The difficulty arises from two distinct causes: one, that as the wheel on the outer rail has to travel a longer distance than the wheel on the inner rail to which it is united by the same axle, one wheel has therefore to slip on the rail, so increasing the friction and abrasion; the second cause is, that the two axles of the car are parallel, while the curve demands that they should radiate from the centre of the curve, and owing to the non-flexibility of the cars in this respect there is great friction between the wheels and the rails. It has been attempted to meet the first difficulty by allowing one

Minimum radius.

See RAILWAYS, *page 59.*

Inconveniences of sharp curves.

Remedies tried.

wheel upon each axle to run loose, so that it can revolve independently of the other, but wheels so arranged soon get out of order. A better plan is to cut the axle in the middle, so that each with its wheel revolves independently, though with the same axial line as the other. This plan, which was tried at first in an imperfect manner, has since been improved and carried out with success at Copenhagen, St. Petersburg, and elsewhere. The necessity for radiating-axles to obviate the second cause of difficulty is met by pivoting the car on short "bogie" carriages, as is done on railways. Such bogie carriages have not (1877) been tried with cut axles, but it is probable that some such combination of the two plans will be found to solve the difficulty. On the great majority of tram-cars it is only attempted to minimise the difficulties above referred to by increasing the width of the groove in the rail or by letting the outer wheel run on its flange, so increasing its effective diameter; and by making the rigid wheel-base of the car as short as possible—an incomplete plan, involving also certain direct disadvantages.

Wheels loose upon axle.

Cars pivoted on bogie carriages.

Gradients.

See also page 59.

3. *The Gradients.*—A hilly city is not favourable for tramways, steep inclines being even more unfavourable to tram-cars than to ordinary vehicles. The superiority which iron rails have over an ordinary road lies in the level smoothness of the surface, the absence of small inequalities, and in the consequent ease of traction. On a level route the advantage of a rail track over the best highway in regard to the haulage power required to keep the cars, when once started, in motion, is as 6 to 1, and if compared with a rough or badly-kept road, is even as great as 10 to 1. Because of this easy traction the tram-cars can be, and generally are, much more heavily loaded than omnibuses drawn by the same number of horses. While, however, the skill of the engineer is thus effectual in reducing friction, the increment of resistance due to gravity on an ascending gradient cannot be reduced, and as the loaded tram-car weighs more than the omnibuses, the resistance is increased in a greater proportion. For instance, on a gradient of 1 in 100, the dead weight of the loaded car has to be lifted vertically one foot for each 100 feet traversed; or assuming the weight of the loaded car to be 8,000 lbs., and therefore this number of foot-pounds to be raised, a force of 80 foot-pounds has to be exerted for each foot of forward motion. And as the tractive force necessary to draw such a car on the level is only about 50 lbs., it will be seen that a gradient of only 1 per cent. (1 in 100) nearly trebles the force necessary to haul the

Superiority of rail track on level.

Resistance due to gravity cannot be reduced.

Measure of resistance on gradients.

car; while on a gradient of 2 per cent. the necessary force would be increased five-fold.

On long lines of tramway, with generally level roads, occasional moderate gradients may be overcome without extra horses; but where the ascents are steep or continuous, extra horses are necessary. Long level tracks with a few sharp ascents are less distressing to the horses than long stretches of even slight incline. The reduction in speed, the strain and wear and tear on the horses, and the consequent increase of working expenses which frequent or steep gradients involve, tell heavily against the profits of a tramway. In London the gradients range from 1 in 25 to 1 in 3,000, there being a few long stretches of from 500 to 900 yards with gradients of 1 in 60, and a few short steep ascents of 1 in 25 and 1 in 30. It is in the substitution of steam or other mechanical power for horse traction that the solution of difficulties arising from steep gradients probably lies. The steam-cars already (1877) tried can ascend gradients of 1 in 15 without difficulty.

Extra horses necessary on hills.

Horses severely strained.

Steam power substituted.
See page 253

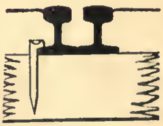
Tramway rails.

4. *The kind of Rail-track and Road-paving.*—Tramway rails have to satisfy two principal conditions, which to some extent are in conflict. The rail must, by a groove, a shoulder, or otherwise, accommodate a flanged wheel, and it must obstruct as little as possible the ordinary traffic of the road. It is obvious that a raised rail, such as is used upon a railway, would interfere with ordinary vehicles, and wherever tramways have been introduced, conformity to rules having regard to this is demanded by the municipal authorities, the conditions being stricter in some cases than in others.

Raised rails inconvenient.

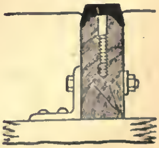
See RAILS *in Part II.*

On country roads, where there is space for the tramway without trenching upon the track of ordinary vehicles, a raised rail may be permissible; but if such a tramway is continued into a town, other rails must be used or the rail must be made level with the road surface; and to do this effectually, a second, or guard-rail, must be placed, as is done on the level crossings of railways. Such a method (which is adopted on some Italian tramways) is not suited for general adoption, and in a climate like that of England the groove between the rails would become obstructed by dirt.



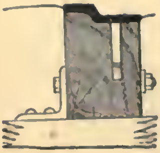
48.
Double or guard-rail.

In the earlier tramways of the United States an almost plain bar of iron was used as a rail, but the flanges of the wheels soon wore an irregular groove or rut between the rail and the road paving. The *crescent* rail, as this is called, although still used on some of the less important lines in America, has been generally superseded by rails of



49.
American crescent rail.

an entirely different kind. The grooved rail (not of the box form used in England) is adopted on some of the tramways in America, but the rails in general use there, while varying on different lines in regard to form, are not grooved, but have in common a wide flat surface and a projecting shoulder—features in which they differ radically from the grooved rails used in England. The American rails are undoubtedly the best for the tramway proprietors (unless they are responsible for damage to other vehicles), for the shoulder gives a sufficient side bearing for the flanged wheel, with less friction than that caused by the grooved rail; the surface is wide enough to allow latitude for irregularities in the gauge either of the track or the car-wheel; and the rail is easily kept clean, a circumstance of great importance in towns specially liable to snow and dirt. Moreover, the rails are wide enough for the wheels of any ordinary vehicle having a gauge which approximates to that of the tramway. It is obvious, however, that the projecting shoulder is a great obstruction to ordinary traffic, and in American cities it is almost impossible for ordinary vehicles to cross the track except at right angles to it. Various kinds of rail have been devised to meet the conflicting conditions above described—the side bearing for the flange, absence of friction, easy cleaning, and at the same time a flush surface for the ordinary traffic. But such attempts have not been successful, and in England and on most of the Continental tramways a projecting shoulder on the rail is not allowed, no condition being more jealously enforced in new concessions than that of the flush rail, which presents the minimum obstruction to ordinary vehicles. In England this found expression in the animated and often acrimonious discussions in Parliament and the local governing bodies, which preceded the authorisation of tramways in 1865-72.



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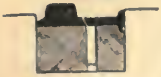

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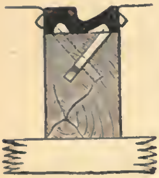
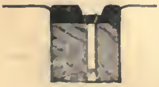


52.

Flush rails obligatory in England.

Grooved rails flush with road.

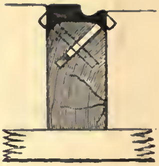
The *grooved* rails, laid flush with the road as on most European tramways, present, in theory, no obstruction whatever to the general traffic of the streets, for while the wheels of ordinary vehicles can run upon the surface of the rails, and, if the line be in good order, cross them without jolting, the groove is too narrow to allow of wheels slipping into it—a liabilty which would obviously render the track unsafe. The narrowness of the groove is, however, an inconvenience to the tramway company, as it is liable to be obstructed by dirt or grit, and requires constant attention to keep it clean.



53.

Inconvenience of grooved rail.

The earlier forms of grooved rail were made with a flat base, and were held down to the sleepers by vertical spikes, this arrangement allowing the rail to be easily fixed or replaced without disturbing the road or substructure; but it has been found that such spikes cannot resist the strains caused by cross-traffic or by the natural tendency of the rail to curve upwards; that the spike-holes weakened the rail and admitted moisture to the timber, causing it to decay; and that some kind of side fastening is the proper remedy. The *box-rail* with holes only in the side flanges is (1877) the shape adopted on most of the new European tramways.



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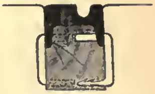


55.

Box-rails

Since tramways were first introduced, the tendency has been towards an increase in the strength and weight of rail. The American crescent rail weighs from 18 lbs. to 25 lbs. per lineal yard, but such sections are only suited for very light cars. The ordinary American flat rails are made of all weights from 25 lbs. to 50 lbs. per yard. The grooved rail with a flat base, as at first used, weighed about 40 lbs. per yard, but the improved box-rail is necessarily heavier, and as moreover it has been found advantageous to increase the strength, such rails are generally made from 50 to 60 lbs. per yard. The expense and inconvenience of re-laying a line are so great, that the extra outlay for a long-enduring rail is amply repaid; and as it is by the action of the ordinary street traffic, and by abrasion from the road grit, and not by the wheels of the tram-cars, that the wear and tear is principally caused, the probable endurance of the rail, and the expediency of using *steel*, must not be measured by the car-mileage. Hardness of surface to resist abrasion is for tramway service the most valuable quality of a steel rail; the great strength under a load and in resisting percussion, which so enhance the usefulness of steel on railways, not being so much needed. The possible use of steam-cars is, however, another reason in favour of steel rails for tramways.

Rails made heavier than formerly.

Advantages of steel rails.

See also in Part II.

Manufacture of tram rails.

Tramway rails are rolled by the same process as are those for railways, and by the same manufacturers, the price being approximately the same; the lesser quantities required at one time being the only reason why the lowest of the prices which sometimes prevail for railway material do not obtain for tram-rails.

Rail-supports made of timber.

See SLEEPERS, *in Part II*

On concrete foundation.

Timber is almost invariably used for supporting the rails, although with a view of reducing cost there are many varieties of method. The rails are laid with a continuous bearing on longitudinal sleepers, which, in all cases, are tied across the track; but engineers differ as to the necessity or expediency of using cross-sleepers below the longitudinal timbers. The rail timbers are on English tramways generally laid upon a foundation of concrete, and without this it is

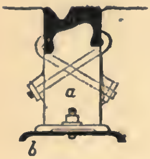
Trouble with road-paving.

difficult even on an old and consolidated road to construct a track sufficiently firm and permanent to resist busy traffic. The principal difficulties with which a tramway company has to contend arise from the incidents and imperfections of the road paving—over which the managers have but partial control; and in the larger English towns the difficulty is intensified by the very heavy street traffic from which many provincial and foreign tramways are free.

Iron supports instead of timber.

New permanent way needed for steam-cars.

Iron instead of timber is preferred by some engineers, as being less likely than timber to yield, and therefore more suited for a permanent standard of construction in the middle of a highway. It is urged by the advocates of iron that the slow and easy motion of a tram-car renders unnecessary the elastic road required for fast-running locomotives on a railway; and therefore full advantage should be taken of iron, as being stronger and more enduring than timber. On the other hand, timber lasts a long time (generally longer than iron rails), and is often more easily obtainable than iron, though it does not show to advantage on those tramways (numerous out of England) where the timber is bedded on the soil without concrete. Iron supports have been designed in various ways. In some, the rails are fixed to iron chairs (*a*), placed at intervals on longitudinal wrought-iron base-plates (*b*), so that the rail has not the continuous bearing it has on timbers. More than 100 miles of this kind of road (the rails being of steel) have (1877) been working for some years with good results in South American cities. In England, cast-iron chairs, with a wide base bedded on concrete, have been laid, and also continuous iron chairs. A few years of working will in England decide the respective merits of iron and wood; but iron is used as yet (1877) in only a few cases. If steam-cars are introduced on tramways which have been constructed only in the manner usual for horse-traction, the permanent-way will probably soon become irregular, and the cars consequently strained.



56.

Iron chairs on iron base-plates.

See IRON SLEEPERS, *in Part II.*

Road maintenance by tramway proprietors.

Conditions on French tramways.

From the commencement of tramway enterprise it has been the almost invariable condition in the concessions, or charters, that the proprietors of the tramway shall pave, and maintain in good order, not only the space between the rails (and where there is a double line the *entre-voie*, or mid-space), but a certain width beyond the outer rails also. Thus, in France, the outside strips of paving to be so laid and maintained by the concessionnaires are 0·450 *mètres* (18 in.) wide on macadam (*empierrées*) roads, and 0·250 *mètres* (10 in.) on paved roads. In England, 18 in. is specified in almost all cases; but the demands of the road authorities have become more exacting than in the case of the earlier tramways, and on some of the metropolitan lines the whole street (up to a width of 30 ft.) has to be paved by the tramway proprietors. In the large cities of the United States, although conditions as to paving and other matters are nominally imposed, the tramway companies assert and are able to maintain a greater independence of the municipal authorities than is allowed in European cities.

Conditions in England.

In America.

As the roads chosen for tramway routes are often only macadamised, it would be cheaper for the tramway proprietors, if their own traffic were alone in view, to maintain the road material as they find it, or, at most, to put a light paving in the horse-track. It is, however, impossible to keep the macadamised roads level with the rails, and even the plan of laying one row of granite setts between the rail and the macadam has been found insufficient where there is much street traffic and variable weather, as in England. On the best-made lines, therefore, it is customary to pave the entire surface which is under the charge of the tramway company with granite blocks or setts; other kinds of stone paving, or wood blocks, being used in some localities. But, whatever be the material with which the road is paved, it is always liable to wear into a rut at its longtitudinal junction with the rail; and the evenness of the road surface being thus disturbed, ordinary vehicles are jolted as they pass over the track, and this, though of little consequence in the case of carts and waggons, is a constant source of grievance to those who ride in carriages. The paving has to be frequently re-laid or adjusted, or in some cases the granite re-worked *in situ*, the rut projections being cut away. Various alterations in the construction of the permanent-way have been tried to remedy these evils, but their success largely depends on the co-operation of the road authorities. As the paving blocks have to be fixed close to the rail, the longitudinal sleepers are necessarily narrow, and lack the solidity which wider timbers would possess; and this close contiguity of the paving to the rail is a cause of difficulty with the iron permanent-way also.

Macadamised roads insufficient.

Granite paving customary in England.

Ruts formed.

The difficulties in connection with the street-paving arise, to a large extent, from the division of authority over the road, and the hurried manner in which the tramways have generally to be constructed. If the entire width of the street could be given up to the tramway engineers for a time sufficient to allow a solid concrete

Divided authority over the roads.

foundation to set properly, and if then the paving were laid uniformly from curb to curb across the street, the tramway being taken as a non-yielding standard level, the chances in favour of maintaining the road in good order would be much increased. Indeed, when a tramway is to be first laid, a convenient opportunity is afforded to the road authorities to construct a good road, or to change a macadamised to a paved road; and they might, with fairness, contribute a reasonable share of the expense. In so far as the tramway company bears the cost of paving a road which is to serve for general traffic, and of the total wear of which only a small proportion is due to the tram-cars, the saving to the road authorities (in London estimated at £200 per mile per annum and upwards) may be considered as rent paid by the tramway company, and in any statement of cost and profit such expenditure may conveniently be kept distinct.

Saving to the public in road maintenance.

Road-paving the chief expense in tramways.

In estimating the cost of a tramway, the road-paving forms the most important item of expense. In English cities, granite setts (generally from Scotland, Guernsey, or Cornwall) are used for paving, and the exact cost of the material, in each case, depends on the distance from the quarries, and the expense of carriage. The paving of some of the most crowded streets of London is formed of granite setts as deep as 9 in., laid on 9 in. of concrete, but 7 in. granite on 6 in. of concrete is the maximum depth for roads along which tramways have (1877) been laid. The cost of picking up and conveying away the materials of a macadamised road is about 1s. to 1s. 6d. per superficial yard (according to the cost of cartage), and the expense of paving depends on the local cost of concrete and granite. Lime concrete laid in place costs, in English towns, from 8s. to 10s. per cubic yard, and the thickness of 6 in., usual as a substratum to paving, may be valued at 1s. 6d. per superficial yard. Granite setts, 7 in. deep and 3 in. wide, cost in London from 33s. to 38s. per ton (including about 12s. per ton for carriage from the quarry), and one ton will, when laid in place, cover 3 square yards, the labour costing about 9d. per square yard. The total expense of altering a macadam road to one paved with granite, averages about 15s. per square yard. Including the first cost of paving, and the expenses of renewals and repairs, it has been found (after taking credit for the selling-price of worn setts) that the cost of granite paving in London taken over a long term of years (excluding a few very exceptional cases), ranges from 10d. to 1s. 6d. per square yard per annum, according to the severity of the traffic.

Granite paving on concrete.

Cost of granite paving.

Cost of maintenance.

It will be seen from the foregoing figures that the paving with granite on concrete of a track 8 ft. wide, as suitable for a single tramway, including 18 in. of paving on each side, will, according to the English standards of price, cost about £3,500 per mile; and of a track 17 ft. wide, for a double tramway, about £7,500 per mile. In many city streets already paved, it is not necessary to lay new concrete and new granite over the whole route, and the cost is so much the less. Assuming an average cost for rails and timber, the outlay, in addition to that for the paving, for a single line in England varies from £1,300 to £1,600 per mile and, for a double line, £2,500 to £3,000 per mile. These rates are exclusive of engineering charges, and the miscellaneous expenses which generally arise in connection with the obtaining of a concession or legislative sanction, the compensation for property taken, for invaded rights, or for law costs; these extra charges together, adding from £1,000 to £3,000 per mile; and in large cities even these sums have sometimes proved insufficient for contingencies that have arisen. Moreover, the expenditure for stables, buildings, and offices, which has also to be added, bears no fixed proportion to the mileage, and is generally heavier per mile for a short line than for a long line. A double line, besides being more convenient, allows more than double the traffic of a single line; and single lines are proportionately dearer than double lines, because of the numerous crossing-places to be constructed.

Cost of paving per mile.

Cost of tramways per mile.

Extra expenses.

Double lines better than single lines.

See page 59.

While the cost of tramways in the larger European cities is so greatly enhanced by the expenses of paving, less onerous conditions than those just described are imposed in many smaller towns with moderate street traffic, or where the standard of excellence in paving is a lower one. Concrete road-foundations are not so common in foreign cities as in England, and granite setts only 4 in. deep, bedded on an old macadam road without concrete, may suffice for the tread of the car horses if there be little other traffic.

Easier conditions of paving.

Concrete omitted.

The *macadamised* roads made, as in English towns, with a surface of broken granite (worth in London about 18s. per ton) on a suitable substratum, cost from 6s. to 8s. per square yard, but the expenses and maintenance vary within very much wider limits. The wearing away of the surface depends of course on the severity of the traffic, which thus determines the quantity of new material required; but in addition to this, the expense depends also on the attention paid to the smoothness and regularity of the surface. Thus, on those of the principal streets of London, where macadam is preferred to

Cost of macadamised roads.

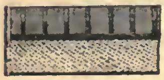
Cost of maintenance.

granite paving (because of its quiet and safety to equestrians), the wear is very rapid, and the new granite as it is applied is consolidated and smoothed down by heavy steam-rollers; the cost of maintenance in such cases exceeding even 2s. per square yard per annum; while on roads where the traffic is much less and the rolling omitted, the cost of maintenance is from 3d. to 9d. only. A macadamised or badly-paved track causes much trouble to the tramway proprietors and inconvenience to the public; and the pitching and jolting of the cars, which on many foreign tramways results from the irregular or neglected road, would not be permitted in towns where the interests of the public are protected.

Wood-paving good but expensive.

Soon decays.

Various kinds of *wood-paving* have been tried in European and American cities; but wood may be considered as an expensive luxury, for while affording a smooth silent surface, it costs more than granite and does not last so long. Although the efficiency of wood-paving may be maintained for about five years at a cost of from 9d. to 1s. per square yard per annum, experience in England and America has shown that the wood decays and wears out rapidly after that period, and it soon becomes necessary or expedient to renew the paving instead of any longer repairing it. The exact term of endurance depends principally upon how far the surface moisture is kept from reaching the substratum of the blocks. Concrete covered with tar asphalte is the best foundation for such paving, the blocks being laid with a space between them which is half filled with hot asphalte and then well grouted with lime and small gravel. From 12s. to 15s. per superficial square yard (in addition to the cost of concrete, as stated above) will embrace the cost in England of the various kinds of wood-paving which have proved successful.



57.

Cost of asphalte paving.

Not suitable for tramways.

Asphalte 2 in. thick, suitable for a wearing surface under city traffic, costs from 13s. to 16s. per superficial yard, in addition to the concrete on which it is laid; and from 9d. to 1s. 3d. per yard per annum, according to the severity of the traffic, will suffice for the cost of maintenance. Asphalte, as affording a hard, smooth, clean, silent surface is very popular where it has been tried, but when made greasy by fog or dirt, it affords a bad foothold; and on a tramway track it chips away at its longitudinal jointing with the rail, and causes ruts.

Tram-cars

5. *The Cars.*—Various kinds and sizes of cars are used on tramways, and the choice is, in each case, principally determined by the climate, the amount of traffic, and the gradients. Although there are

great differences in the length of cars, the width is generally from 6 to 7 ft.

One-horse cars.

One-horse cars vary from 8 ft. to 15 ft. in length, seating from 10 to 22 persons. An open one-horse car weighs, when empty, from 20 cwt. upwards, and costs about £100. A closed car weighs from 24 cwt. to 30 cwt, and costs from £120 to £180.

Where suitable.

One-horse cars are most suitable for level lines, where there is a small or constantly changing traffic; the tramway in such cases being much more likely to be popular and profitable if small cars run frequently, than if large cars run at longer intervals.

Cars as used in Brussels.

This principle is, for instance, adopted in Brussels, where there is a large traffic, none but one-horse cars being used; although one, two, and sometimes even three extra horses are added for ascending the hills. It is in some cases of such use of one-horse cars that the few instances of narrow-gauge lines occur. As one-horse cars weigh more, in proportion to the accommodation they afford, than two-horse cars, either the passengers must be limited in number, or the strain upon the horses be increased, and therefore it is very important to keep the weight as low as possible. Where the wages of two men would bear heavily on the earnings of the smaller one-horse cars, the passenger fares may be collected by the driver;

Fare-box system.

and what is known as the "fare box" system has been successfully adopted in America and in some European towns to meet such cases. As the passengers pass into the car they deposit the fare in a box by the side of the driver, he being furnished with packets of small money for those who need change; but no change is given for coins dropped into the box.

Two-horse cars.

58.

Dimensions, weight and cost.

If the numbers in all countries be reckoned, the great majority of cars hitherto (1877) constructed are for two-horse traction, and for inside passengers only. Such cars generally vary in length from 10 ft. to 16 ft., and have seats for from 14 to 24 passengers, although, in the absence of effective bye-laws, a much larger number will crowd on or into the car. The weight of two-horse cars of this kind ranges from 25 to 36 cwt.; and the cost from £170 to £200, the exact price being determined not only by the size of the car, but by the nature of the fittings, ventilators, cushions, lamps, and other appurtenances.

Height of cars.
See BRIDGES, *page 144.*

Cars having only inside seats generally measure about 9 ft. 6 in. from the ground to their highest point, and a corresponding headway is necessary under bridges which cross the track.

Tram-cars for cold climates.

In climates as cold as those of England, Germany, and the northern parts of France, cars entirely open are seldom used, except occasionally as workmen's cars at low fares; but as in such climates omnibuses

59.
Outside seats.

with outside seats are customary, tram-cars are also constructed to carry passengers on the roof, there being generally about an equal number of seats inside and outside; the total number ranging from about 36 to 56. Thus in Berlin there are cars with seats for 56 passengers, while in London the cars are generally made about 16 ft. long, weigh from 45 to 55 cwt., and have at most seats for 44 persons, crowding beyond the prescribed number being prevented. In London, the cars measure about 11 ft. 6 in. from the ground to the topmost rail, and a minimum headway below overhead bridges of 13 ft. 6 in. is necessary even for seated passengers; but 16 ft. is required for the safety of passengers who might stand up. The extra weight of outside seats and passengers renders such cars unsuited for lines with steep or frequent gradients; but if steam traction be generally adopted, it is probable that heavily-loaded cars will be more common. Some of the cars made in Germany for the earlier tramways there, are almost entirely of iron, weighing from 70 to 80 cwt., and this unnecessary weight of course reduces the amount of paying-load that can be carried. When experience has been gained in the working of a tramway, economy may be greatly promoted by choosing—as the periods of renewal occur—cars of a size suited to the average number of passengers, so avoiding the unremunerative haulage expenditure, which large but only partially-filled cars involve.

Iron cars.
See ROLLING STOCK, *in Part II.*

Classing of passengers.

Outside seats afford an additional facility for classing the passengers, and the necessity for a division of classes is becoming apparent to render the tramways useful and popular among a mixed population. Even one-horse cars are sometimes constructed to carry two classes of passengers; such cars having room for four of the lower-fare passengers at each end, and six or eight high-priced seats in the interior. Already (1877) in some towns the cars are divided into 1st, 2nd, and 3rd class, and even occasionally 4th class at very low fares for workmen. Even in St. Petersburg, during the winter, passengers travel at the lower fares outside the cars; but in some places where the cold renders outside seats unpopular, but where the traffic is great and a level road allows easy traction for heavy loads, two-storied cars are used in the winter, the upper tier being enclosed with sides and windows somewhat in the same way as are the two-storied carriages on the suburban railways of Paris, and elsewhere. Tram-cars of this kind are, for instance, used in Hamburg and Copenhagen, and are sometimes made so that the

60.

Two-storied cars.

Upper cover removable.

cover of the outside seats may be removed in the summer. In Christiania (Norway), where the tram-cars are in winter stopped by the snow, and where the non-employment of the men and horses would cause serious loss, the plan has been successfully tried of placing one-horse cars upon sleigh runners with two horses, the cars running only half as frequently as in summer, but at double fares.

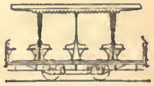
61.

62.
Winter car.

Cars with outside seats on the roof are seldom used in hot climates like those of India, South America, Spain, or Italy, though occasionally outside seats with awnings are employed; but in some of these countries, during the hot seasons, the car windows are removed, and louvre-blinds (*persiennes*) substituted, and it has been proposed to make the cars so that the body may be in summer removed from the platform, and seats covered by an awning substituted. Cars with a roof only, or even entirely open, are used in summer (often specially as cars for smokers) in Italy, Spain, South America, and elsewhere; awnings and curtains being provided as a shelter from the sun; and in some Italian cities none but open cars are used. The seats of open cars are usually arranged *vis-à-vis* across the car, and sometimes, where the traction is easy, such cars are made as long as 25 ft., weigh about 32 cwt., and seat 40 persons; but more often the length is from 12 ft. to 18 ft., the seats from 16 to 32 in number, the weight from 20 to 30 cwt., and the cost from £100 to £140.

63.

64.
Summer car.


65.
Open car.

American-made cars.

Chilled wheels.
See also in Part II.

Superseded by steel.

The cars on the earlier European tramways were obtained from the United States, where the manufacture had become an important one; and even afterwards, when the cars were made in England, the wheels were imported, the American *chilled-iron* wheels being specially hard and durable. Since tramways have been thoroughly established in Europe, the cars are entirely made in England and in the chief continental cities, and the chilled iron, though still sometimes used, has been generally superseded by *steel.* For use on tramways beyond European limits the choice between European and American cars must mainly depend on the facilities for shipment and the cost of freight.

Packing of cars for export.

Freight by measurement.
See EXPORT *in Part II*

For export, the wheels and platforms can be placed inside the body of the car, which is generally packed as a whole in a large case; though generally, if the wheels be fitted to the axles, they are packed separately. The freight is always by "measurement" tonnage or at special rates, the dimensions being approximately ascertainable by an allowance of 3 in. on all sides of the car, and

Cars carried as deck cargo. when because of the bulkiness of the packages they have to be carried as deck cargo, high rates of freight are sometimes demanded. The packages add about 5 per cent. to the cost of the cars.

6. *The Hauling of the cars either by Horses or Steam traction.*—The horsing of the cars is one of the most important incidents, as it is generally the most troublesome, in the management of a tramway. Great care and judgment are necessary to maintain the animals in a state of efficiency, and to obtain from them the maximum of service. Sufficient and suitable food, clean and well-ventilated stables, careful shoeing, a not excessive amount of work, and regular rests, are the necessary conditions. The mileage which the horses can work in a day depends, of course, on the weight of the cars and the gradients. In London, a two-horse car, running 70 miles per day, usually requires ten horses, each horse thus having 14 miles of work. But to maintain this service, eleven horses are provided so as to allow for occasional rests. But where the cars are light and the gradients very favourable, horses are worked 16, 18 and even 20 miles per day. Of course, in each case the strength and endurance of the animal, its first cost, and the expense of maintenance must be considered together; but, unless the price of horses or mules be very low, it will generally be found more economical—apart from merely humane considerations—to work the horses for moderate distances only. The London General Omnibus Company, by careful selection of their horses, and proper treatment, raised the working-life of the animals from three and a half years to five years. In the working of tram-cars, the brakes save the horses from the severe strains in stopping which tell so severely on omnibus horses, but this advantage is more than outweighed by the severer strain they constantly undergo in starting the cars; the rails affording but slight assistance in overcoming the inertia, which is greater (because of the heavier weight) than for the omnibus. The working-life of tram-car horses is, therefore, generally shorter than that of omnibus horses. In England, the horsing and working of the cars costs about 9d. per mile for two-horse cars, this sum including charges for forage, shoeing, harness, and horse renewals; care and attendance; conductor and driver; but excluding the first cost of the horses and everything connected with the road and superintendence. As the forage for the horses (at the rate of 13s. or 14s. per horse per week) absorbs nearly half of the 9d., it is obvious that fluctuations in the cost of provender will have great effect upon

Horsing of cars.

Conditions of good maintenance.

Horse mileage per day.

Working-life of horses.

Service in cars and omnibuses compared.

Cost of horsing.

Cost of provender.

profits. Any statement of the cost of horsing per mile is, however, incomplete unless the weight of the car and the number of passengers be also stated, for a low cost per mile because the cars are only half-filled and therefore easy to haul is evidently fallacious. In many countries mules are used in preference to horses for service on tramways.

Mules.

The rapid increase in the number and extent of tramways since their first introduction, the difficulties presented by steep gradients, and the large proportion which the cost of horsing bears to the total working expenses, have naturally suggested the use of steam or other mechanical means as a substitute for horses. The application of steam-power is possible in many ways, but the adoption of any particular system has been delayed by the laws or regulations which forbid—except under stringent and often impossible conditions—the running of steam-cars in the public streets. In England, even in rural districts, the use of traction or road engines is (1877) permitted only under regulations which would prohibit their successful use on tramways. The nuisance of the smoke, the frightening of horses, and the supposed difficulty of controlling the engine, are the principal objections raised, but it has been so clearly shown that engines can be made which do not involve such risks and inconveniences, that in many towns in Europe and America steam-cars are already (1877) at work, while in England and on the Continent the authorities are conducting or watching experiments with a view to the establishment of less stringent regulations. Although the particular system which will be finally adopted is not likely to be agreed upon for some years to come, till experience shall have proved which is best and cheapest, there is a common agreement among engineers and others able to judge, that the cost of haulage will be reduced at least one-third below that incurred for horse-cars, the greatest saving being obtained in those cases where the traffic is sufficient to keep large cars employed. Horses, although capable of sudden or exceptional exertion, are yet injured by the repeated heavy strains which starting a car or dragging it up a gradient involves; while a steam-engine can be so arranged as to give out at the will of the driver, according to the service demanded, and without injury to itself, an increase of force subject only to a proportionate additional expenditure for fuel.

Substitutes needed for horses.

Steam-power.

Prohibited by law.

Objections to steam on highways.

Objections proved fallacious.

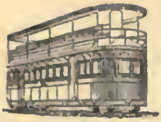
Economy expected from steam-power.

Reserve force in steam-engine.

Although the saving obtained by the use of steam instead of horses on tramways with established tariffs of fares, would sometimes

Saving by steam shared by public.

be retained as profit by the proprietors, it is probable that the authorities in conceding the use of steam, might demand, in the public interest, some share in the saving. Such permanent reduction in the cost of working must also eventually tend to a better and cheaper service, and tramways will thereby be rendered possible in towns where the gradients forbid the profitable working of horse-cars.



66.
Self-contained steam-cars.

The principal differences in the various steam-engines which have been tried on tramways consist in the modes of separating the engine from the passengers. In some cases the engine is on the car, shut off from the passengers by a partition; but in regard to the objections sometimes raised against this close contiguity, it is probable that passengers would by use become as indifferent as in the almost similar circumstances on a steam-boat. Very little difference is perceptible between such a car and an ordinary horse-car. Although smoke is prevented, an awning is necessary to protect passengers riding on the roof from the fumes from the chimney. In other cases a separate or locomotive car, boxed in to hide any appearance of machinery or steam, is used for hauling the passenger-car; the capacity for hauling a second or extra passenger-car being common to both kinds of steam-car, according to their power and adhesion, and the gradients. Each presents some advantages. The first kind occupies less room in the street, and the weight of the passengers is effective in giving adhesion to the engine wheels for overcoming gradients: in the latter kind the engine and boiler are more effectually separated from the passengers, and can be immediately detached for repairs; but as the capacity of an engine for hauling is limited according to its weight on the rails—whatever be its power or the pressure of the steam—a locomotive or hauling-car would have to be loaded to obtain sufficient adhesion for overcoming steep gradients; an effective weight of not less than 6 tons on the driving-wheels having been found necessary even on slight gradients. Further, where the traffic is sufficient to employ larger cars than two horses could draw, steam-cars for carrying even as many as 60 passengers can be constructed; the services of the conductor and driver being thus more profitably employed. With the engine as part of the car, the effective weight for adhesion increases with the number of passengers, but a separate or locomotive-car would require always to have in itself the adhesion-weight required for the maximum load to be hauled. Moreover, the engine from a steam-car can be easily withdrawn from the car, and (if need be) packed up and

67.
Separate or locomotive car

Adhesion-weight on rails.
Se RAILWAYS, *page 59.*

Advantages of self-contained steam-car.

sent a considerable distance for repairs, in the absence of a local engineering establishment; the car continuing at work with a spare engine. On the other hand, the lighting of the fire and the cleaning of the engine in such close contiguity to the passenger-car may prove inconvenient. Some years of working will be needed to show which kind of engine is the best. The separated locomotives hitherto tried, boxed in to resemble small cars, weigh from 4 to 8 tons, and cost from £550 to £900. The self-contained steam-passenger-cars for 40 to 60 passengers weigh from 6 to 10 tons, and cost from £800 to £1,200.

Weight and cost of steam-cars.

The capital outlay for horses and that for steam-cars do not differ very much, the saving which the use of steam allows being in the cost of working and maintenance. A decision in any particular case depends very much on local circumstances; for instance, where horses or mules are plentiful, and coal dear (which conditions are found, for example, in some South American towns), it would seldom be expedient to bring steam-cars and drivers from a distance, especially if the gradients be easy. As in horse-cars the strains in stopping and starting are the severest for the horses, so in steam-cars, the fuel expended in each stoppage bears a large proportion (estimated by some engineers as equal to that for half-a-mile of haulage) to the total consumed. The expediency of stopping only at appointed places will therefore possibly arise.

Choice between steam and horses.

Mechanical power without the use of steam upon the roads is obtained by the employment at the terminus of the tramway of a fixed engine for compressing air which, transferred to a container on the car, supplies the engine. Such a method, if practically successful, would offer many advantages, but certain difficulties which attend the employment of compressed air are increased in tramway service. To the cost of a tramway car, worked by an air-engine, have to be added the expenses of the steam-engine and apparatus at the stations for compressing the air and for charging the container. The expenditure of fuel for compressing air is greater than that by which the same power can be produced directly from a steam-engine. Further experience is (1877) therefore needed to allow a proper comparison with the steam-car.

Compressed-air engines.

Further experience needed.

7. *Working expenses.*—The working expenses of a tramway of course vary according to the nature of the service and the expenses of forage and superintendence; but the relation which the expenses bear to the gross earnings obviously depends on the tariff of fares.

Working expenses of tramways.

The experience gained in the working of tramways in different countries shows that a remunerative return for the capital outlay has generally been obtained when not more than from 70 to 80 per cent. of the gross earnings is consumed in working and maintenance. On English railways it has been found that some percentage between 50 and 55 is generally the highest which will allow a surplus sufficient for a fair dividend; but the cost of land and works is generally much greater than on a tramway, and the earnings per car per mile very much less; so that a larger portion of the receipts on a railway must be applied to meet the interest on the fixed capital.

Compared with railways.
See page 65.

Tariff of fares.

8. *The Tariff of fares.*—Although similar rates of fares do not when expressed in the currency of different countries exactly coincide, 1½d. to 3d. may be said to embrace the various rates charged on most European tramways for distances up to 3 miles, and sometimes —generally on level roads—a ride of even 4 miles is allowed for these rates; and fares higher than 4d. are seldom charged anywhere. Specially low fares prevail on some of the open cars used on the Continent and in America, and also on those cars which are divided into classes. On some English tramways low fares are charged at early hours for workmen; and stipulations to that effect are sometimes embodied in the authorising Acts of Parliament. In some concessions there is no stipulation as to the tariffs of fares, but the rates have to be approved by the local authorities. In England a maximum tariff is generally fixed, within which the proprietors may arrange the actual rates as they please.

Cheap fares for workmen.

Obligations on tramway lessees.
See also page 33.

9. *Minor Obligations, Privileges, and Bye-laws.* — Certain obligations are imposed on the proprietors or lessees of a tramway besides those already described. Such are the maintenance of a regular and sufficient service; the rates of speed; the cleanliness of the cars; and stipulations as to the temporary stoppage or diversion of the track to allow of access to sewers or pipes. Other conditions are sometimes demanded by the authorities, such as, that cars shall be run at early hours at low fares for workmen; that firemen, postmen, and telegraph messengers shall, when on duty, be carried free; or that the free use of the line shall be allowed in the night for municipal cars containing road material, sewage matter, or refuse. Demands of this kind obviously depend on the local circumstances or necessities of each case. Thus, for instance, in Berlin the military authorities have stipulated for a free right of way for ambulance tram-cars over those lines which connect the barracks and the hospital.

Gratuitous service demanded.

In the concessions or charters which authorise the establishment of tramways, certain secondary privileges are necessary in the interests of the proprietors, besides those which convey the monopoly and right of way. These privileges are sometimes specified in the concession or enactment by which the tramway is authorised; but sometimes many of them are left for embodiment in bye-laws drawn up and published by the managers of the tramway, with the sanction of the police or municipal authorities. Such regulations, or bye-laws, define the times and conditions under which the roadway may be blocked for repairs to the tramway, and forbid the obstruction by ordinary vehicles of the passage of the cars. Other regulations are framed for the comfort of the passengers, and refer to such matters as over-crowding on the cars and unnecessary halting. Powers are generally given to the tramway company for the recovery of penalties for infringement of the bye-laws.

Privileges.

Regulations and bye-laws.

Penalties

As conveyed in the foregoing pages, the cost of a tramway, the choice of materials and equipment, and the probabilities of profit, depend entirely on the local circumstances of each case; and in the following summary are recapitulated those particulars which must be furnished to allow of the proper consideration of a scheme by engineers and capitalists.

Tramway projects.

Particulars enumerated.

1. A map of the city or town and its suburbs, showing the streets, railway-stations, markets, and public buildings, the routes of existing omnibus lines, and the proposed routes for the new tramways. **Map of town.**

2. The population of the town and suburbs, and statistics as to the growth of population. **Population.**

3. Plans and sections of the tramway route, showing the width of the road and foot-paths at all points, and the gradients. A description of the buildings and shops along the whole route should accompany the plan. **Plans and sections.**

4. A description of the streets in regard to the kind of paving and substratum, the method of draining, and the order in which the surface is kept, together with the method adopted for cleansing and mending the roads; information concerning the sewers or pipes below the roadway, and the frequency of repairs, so far as these may affect the tramway. **Streets described.** **Road-paving.**

5. The number and kind of omnibuses and cabs, how far they are sufficient for the traffic, the privileges or obligations under which they ply, the rates of fares, the number of passengers, and, as far as can be ascertained, the profits earned. **Omnibuses and cabs.**

Horses and provender.

6. The kind of horses or mules obtainable, and the prices; the cost of provender, and whatever else determines the expenses of maintenance.

Climate.

Kind of traffic.

7. Information as to the climate; the means, habits, and occupations of the inhabitants, and the nature of the traffic between the city and the suburbs, so far as they will influence the business on the tramway, or by which the kind of cars may be determined.

Materials and labour.

8. Information as to import duties, cost of transport, materials, and labour, so far as they may be likely to apply to tramways; and, specially, particulars concerning the kind and cost of timber for sleepers, materials available for concrete (shingle, gravel, sand, and lime), and for paving the streets.

Terms of concession.

9. The conditions under which a concession has been, or may be, obtained, with the nature of the privileges and obligations.

Tramways for goods traffic.
See also page 231.

On country roads.

Difference between tramways and railroads.

Gradients forbid horse tramways.

Although tramways for the conveyance of minerals and merchandise were in operation long antecedent to railroads, a new stimulus has been given to this branch of enterprise by the rapid extension of town lines for passengers. Rail tracks upon highways, for vehicles with flanged wheels will probably become more common; while, if steam-cars become fully established in towns, their adoption for longer distances on country roads will follow in many districts where the roadways are suitable. Traction by horse-power, or by fixed engines, or by something other than locomotives, has been generally accepted as that which distinguishes tramways from railroads, but if the use of steam on highways becomes general, the classification—if it be retained—may also depend on the speed, and may so include in the category of tramways those lines on which the loads are carried by steam-cars. A rail-track affords—after canals and navigable rivers,—the cheapest means of transport, and the use of steam overcomes the greatest obstacle which has hitherto prevented an extended use of tramways. For while on level roads even horse-traction allows on a rail-track an enormous saving in the cost of haulage over that incurred on an ordinary highway, occasional hills almost entirely neutralise the apparent benefits. But though a ruling-gradient of even 2 per cent. may thus effectually hinder the success of a horse-tramway, the latent or reserve force in a steam-engine overcomes the difficulty.

Raised rails on highways.
See also page 241

The grooved rails used on town tramways are quite unsuitable for service on country roads, and raised rails which cannot conveniently be crossed by ordinary vehicles are alone suitable; but as in many countries the highways are, or can at small cost be made, wide enough to allow a rail-track on one side without diminishing too much the space for ordinary vehicles, it might prove advantageous in a colony needing development, and where new roads are being made, to lay out such roads so that a tramway for steam-cars might be added at a future time. If a line can be laid in this way, many of the expenses incurred in a railway project for land and works, can be avoided; and as the maximum speed need not exceed ten miles per hour, and as the cars can at such a speed be stopped within half their own length, no fencing of the track nor signal apparatus is necessary. A tramway of this sort might be of great convenience in wide, sparsely-peopled districts, as instead of stations few and far between, passengers and light goods could be taken up on the route, or at any rate at all cross roads; platforms or cranes for heavier merchandise being only provided at special places. In districts with only a small traffic, a more frequent, and therefore a more convenient, service could be maintained than the same expenditure on a railway, even of narrow gauge, would allow. For instance, on a road ten to thirty miles long from a seaport or railroad station, where a traffic of only one hundred passengers and 20 tons of goods each way per day had to be carried, one mixed train (for goods and passengers) would suffice, and if the load were divided over two or more trains, the mileage would be proportionately and unprofitably increased, as the train, even for the diminished load, must still have a certain number of vehicles. But if instead of one railway train, four steam-cars—two for passengers and two for goods—were running each way at suitable intervals daily, the service would be more convenient, and probably cheaper.

Expenses of railway avoided.

See pages 3 and 58.

Tramways suitable for small traffic.

See also page 66.

Steam tram-cars cheaper than trains.

Adhesion-weight of locomotives.

On a railway, the locomotive must have a certain weight to give the wheels the necessary adhesion to the rails, and the machinery necessary under ordinary circumstances for the primary purpose of power and speed provides this weight, but the proportion which this adhesion-weight bears to the load to be hauled increases rapidly with the gradients, and even if the inclines be few, the steepest or "ruling gradient" determines the weight and power of the engine. In a hilly or even an undulating country, gradients of 2 per cent. occur, and inclines of 4 and 6 per cent are not unusual. On a railway such gradients are avoided, where possible, by cuttings, embankments, and tunnels, or by a circuitous route; but if it be desired to take advantage of a highway, the existing gradients must be accepted; although it may prove beneficial occasionally to leave the highway for the sake of avoiding or cutting through a hill. The necessary weight of a locomotive increases rapidly with the gradients, heavy and expensive engines being necessary for steep inclines; the weight of the engine and trucks giving a non-paying load great in proportion to the paying load. But, on a tramway, the lightest engine that can be designed to afford the necessary power can be employed on a self-contained steam-car, adhesion being partly given by the paying load which is carried.

Weight necessary on gradients.

See also pages 59 & 240.

On steam-cars paying-load gives adhesion-weight.

General superiority of railways.

The superiority in regard to speed, power, and other important qualities which locomotives on railways have over any other applications of tractive force in the majority of cases, is obvious; and it is only intended in the foregoing remarks to point out that where the traffic is small there may be peculiar cases where the alternative of steam-cars is worth consideration.

Only on the basis of a full knowledge of the facts can the merits of the two systems be weighed; the particulars most necessary among those already enumerated for railways and tramways being those which refer to the nature of the road, the gradients, and the amount and kind of traffic.

[*See also* CONCESSIONS: RAILWAYS: *and*, *in* PART II., RAILWAY EQUIPMENT AND ROLLING STOCK.]

CHAPTER XIII.

MARKETS.

Necessity for markets.

THE demand for increased market accommodation keeps pace with the growth of modern cities; and there are few ways in which the welfare of the inhabitants—especially the poorer classes—can be better promoted than by thus facilitating the purchase of commodities. By concentration at one place or under one roof, the commerce in provisions, as well as the cost of transport and distribution, are made easier to the trader; a better and generally cheaper selection is available to the purchaser; and time is saved to all. To the municipal authorities, too, a market offers facilities for the sanitary examination of food, the inspection of weights and measures, and—where such customs prevail—the collection of taxes. The new market benefits the town by attracting the inhabitants of surrounding districts; and if railways be established, they afford the double advantage of bringing into the market traders with produce to sell and purchasers with money to buy.

Advantages afforded by markets.

Modern markets.

During the thirty years ending 1877 new and well-arranged covered markets have been erected in the principal English towns, and in many of the chief cities on the Continent. The large markets for cattle, meat, and poultry erected by the Corporation of the City of London; the market halls in Manchester, Leeds, and Bradford; the Halles Centrales in Paris; the markets of

Examples.

Bordeaux, Brussels, and Barcelona; and the magnificent markets in Madrid, and Santiago (Chili)—all erected within the period mentioned—may be cited as leading examples of modern practice.

Markets generally established by the municipality.

The establishment or improvement of a market is almost always undertaken by the municipal authorities, and is second only in importance to sanitary works. Markets should, as fit projects for official management, take precedence of such undertakings as gas or water supply, which may with more propriety be left to private enterprise. In very many cases new markets are erected upon town lands—often upon the site of an old market—and the undertaking is free from the burden of ground-rent. Market tolls frequently form the oldest and most important source of municipal revenue; and if money has to be borrowed for the erection of new buildings, the tolls or rents may be found sufficient to pay the interest. But in some cases the need or the desire for improved accommodation induces the municipal authorities to expend considerably more than the existing income will provide for; and although a revenue greater than in the past may be expected from the improved markets, it may be expedient to wait for a gradual growth of income, rather than to impose immediately rates of tolls sufficient to defray the necessary interest on the outlay. It is to the advantage of the community that a market shall be as free as possible, not only because of the direct benefit obtained in the cost of commodities, but because there should be no impediment to the market becoming a centre or entrepôt for a widely extended trade. Railways and other improved means of communication have a double effect, for while useful to persons going to market, they facilitate also the sending of goods directly from the producer or merchant to the customer; the results of which are evident in the gradual decline of fairs as trade-centres. Although markets will always be useful for local transactions, their outside trade will dwindle and decay if burdened with charges or troublesome restraints. So long as the tolls demanded (considering, of course, the conveniences afforded) do not exceed what a free competitition outside the market would produce, then the revenue may be considered only as rent; but if by stringent regulations imposed on outside traders, or by the granting of monopolies or privileges to the stall-holders inside the market, free competition is prevented, the higher revenue so obtained becomes in effect a tax on commodities, which involves many of the evil effects of an *octroi* duty.

See pages 166 and 209.

Revenues from market-tolls.

Increased accommodation found necessary.

Markets should be free.

See page 2.

Decline of fairs as trade-centres.

Equitable tolls reckon as rent.

Excessive tolls reckon as taxes.

See page 182.

Cost of markets, how defrayed.

In England, if the cost of new markets cannot be defrayed out of municipal funds, arising from public lands or other property, there is seldom any difficulty in borrowing money on the security of the rates, with or without the collateral security of the market buildings and tolls. In cases like these, the necessary works are entrusted to contractors, who are paid in money; and the markets, when completed, and the revenues derived from them, become municipal property. In some foreign countries, however, the necessary funds cannot be raised in the locality, and the assistance of outside capitalists must be obtained. If the credit of the municipality is good, and the surrounding circumstances are favourable, the money may be borrowed on bonds, by which the town is pledged to pay a certain interest, and to repay the capital. The precise methods of doing this are various, and many of them afford opportunities for combinations of local investors and outside capitalists profitable to both. The revenues of the market may be pledged as a collateral security for the bonds; and the tolls may be set aside for the purpose, or even collected by the representatives of the bondholders till the debt is redeemed. The want of markets may even be so manifest, and the anticipated revenue so considerable, as to induce capitalists to undertake the construction of the markets, and to look solely to the revenue as a return. A concession then becomes necessary, and the municipality will have to grant facilities, immunities, or advantages, to induce capitalists to embark in such an enterprise.

Loans. *See pages 30, 41, 183.*

Town bonds. *See pages 168 and 185.*

Tolls pledged as security for loans.

Concession granted. *See Chap. II.*

Free site granted.

The gift of a free site is one of the first points in which aid may be afforded to the concessionnaires, and the next is the granting of a monopoly. If no proper market-buildings have as yet existed in the town, or if the new structure is to replace the only existing market, the monopoly may be absolute: the concessionnaires having also the sole right, and at the same time the obligation, of building any new market that may be required; but in the case of a large city with existing markets the monopoly may be granted for a certain district only. In the interests of the concessionnaires, and to make the monopoly a real one, it should be stipulated that no stalls in the streets, or public trading other than that in shops, should be permitted in the prescribed district; and although such a course may involve certain disadvantages to the town, they must be considered as part of the price to be paid for what on the whole affords increased accommodation and convenience. In some cases the sale of certain articles may be confined entirely to the market: meat

Monopoly granted. *See page 27.*

Street-stalls forbidden. *See page 28.*

Monopoly of sale of meat.

is sometimes in this way the subject of a monopoly, no butchers shops being permitted elsewhere, and such a restriction or a similar one in regard to fish may be justified for sanitary reasons. The sanitary restrictions are often directed—frequently in connection with schemes of drainage—to the regulation of private slaughter-houses; their entire abolition, and the substitution of public *abattoirs*, being sometimes included in the concession for a new market. Where water-works or public fountains are already established, concessionnaires may stipulate for a gratuitous supply of water to the market; or, if this cannot be granted, for a certain quantity per day at favourably low prices.

Abattoirs.

Free water-supply. *See pages 172–7.*

Dues and taxes.

The concession should declare to what dues, imposts, taxes, or *octroi*—if any—the markets, or the goods sold, or the revenue from the market, will be liable. The enterprise may be encouraged by allowing immunity from import-dues for the material of the market, and from taxes of any kind on the revenue. If it be inconvenient to make a binding agreement for such immunity for the future, the concessionnaires should stipulate that at least no taxes be imposed in the future, which are not made to bear equally on all other traders in the town. In many towns where *octroi* duties are levied, bonded warehouses might with advantage be constructed in or near the markets, so that provisions or goods might be sold from sample, and the dues paid only as the goods were removed. By some such means the delays and inconveniences which always attend the collection of an *octroi* tax—and which are often unnecessarily aggravated by the examination at the barriers or gates of a town—would be reduced to a minimum.

Immunities. *See page 26.*

Bonded warehouses for octroi collection.

Maximum rents and tolls agreed upon. *See page 34.*

The concession should state the maximum rents or tolls which the proprietors of the market will be permitted to charge to the stall-holders. Such rents are generally calculated according to the size and position of the stall. For wholesale traders inside or outside the building, the dues may be imposed according to the number, weight, or value of articles sold, and the accounts which are necessary to such a system offer a convenient statistical record of the commodities sold. It is, however, generally found better to arrange a tariff according to the space occupied, and occasionally the two plans are combined so as to obtain, besides rent, a payment in some degree proportioned to the business transacted. Thus, in the London Meat Market, where the principal trade is wholesale, one penny per superficial foot of space per week is charged as rent, and, in addition,

Rent and tolls combined.

a toll is levied of one farthing on every 21 lbs. of goods. As the total quantity of provisions brought into the market approaches 200,000 tons per annum, the revenue from this source, even at such a low rate, is considerable. The corner stalls of a market, or those situated in a central position, are generally sought after, and command a higher rent than other stalls; but prominence of position is of less importance to the trader in a wholesale market than in a retail market, where a conspicuous display assists in attracting chance customers. As the worth of a concession will, of course, depend on the amount of revenue obtainable, and on the proportion which this bears to the cost of the market, and as mere permission to charge certain rates will be unavailing if no tenant be found to pay them, great care must be taken by inquiry among traders, and by comparing the rent of existing markets, stalls, or shops, to ascertain what prices traders will be able and willing to pay for accommodation in the new market. Where the population is a growing one, an increase in the letting-value of the stalls in a well-placed market may be fairly expected.

Corner stalls preferred by traders.

Rent of stalls regulated by rent of outside shops.

Opposition to a new market is not unfrequently manifested by traders already established in shops or in an existing market, who may apprehend loss to themselves from a rival undertaking; and opposition of this sort may often be conciliated or neutralised by giving the first offer of stalls in the new market to such established traders; and the same or even an earlier preference may be granted to street-sellers, the stoppage of whose business it may be one of the objects of the new markets to attain. The right to establish markets is, when retained by the town authorities, considered permanent as well as exclusive, but where the privilege is granted by a concession to others, the monopoly should be for a term of years, 40 to 80 years being usual terms. If the markets are to become the property of the municipality without payment at the end of the term, then it will be necessary to set apart from the revenue a sinking fund for paying back the capital; but the municipality, instead of requiring a free transfer of the property, in some cases only reserve to themselves the right of purchasing the markets on certain conditions defined beforehand. Investors, as a rule, prefer the gradual return of their capital, and if a sufficiently good dividend be secured to them, will not be unwilling to give up their property after a certain fixed period. The supposed value of the privileges granted will determine what period will be remunerative to the concessionnaires.

Opposition to new markets.

Markets generally a town-monopoly.

Length of lease to concessionnaire.

Sinking-fund. *See page 37.*

Obligations imposed.
See page 33.
Suitable buildings required.
Unproductive expenditure.

A municipality, in granting a concession for markets, imposes certain obligations in return. It may be presumed that the primary object with the authorities is the establishment of good markets; and they will require to be satisfied with the size, appearance, and fitness of the new structures. A municipality will naturally prefer buildings of imposing or handsome appearance; but, while it is the duty as well as the interest of the promoters to erect buildings which will be creditable to the town and themselves, they cannot afford to spend much money on unproductive ornament, if their only return is to be derived from the market tolls. This applies particularly to the height of the buildings and to domes or towers, because when the space for stalls has once been enclosed, and sufficient height given for ventilation, all beyond adds greatly to the cost, without adding to the earning capacity of the markets.

Choice of site.
Site of an old market the best.
Central situation.
Conspicuous position.
Good access necessary.

Although there are various considerations of locality and purpose which differ in each case, there are certain main features or conditions which are common to markets everywhere; and one of the first and most important is that of the site, for if this be badly chosen it will, so far as the use of the market and the revenue derived from it are concerned, neutralise what in all other respects may be complete. The site of an old and well-frequented market is generally best for a new structure, as people have traditional habits in such matters, and prefer to go to an accustomed place. A central spot, where many streets converge is a good situation, and in such cases the commerce of a market may even be promoted by making the main avenues useful as public thoroughfares for foot-passengers; or, if it is sought to build the market in a public square or plaza, for vehicles also. This arrangement obtains in the London Meat Market at Smithfield, where a main street bisects the structure, passing through it under cover, and there is a somewhat similar arrangement also at Paris. If so central a position cannot be obtained, then a site between two important streets should be preferred, or at any rate a site where one or more entrances to the market may open, and be conspicuous from, a much-frequented thoroughfare. As it is an advantage to have numerous points of access and exit, entrance gates or doors should be freely provided on all sides of the building. Contiguity to railway-stations, to an important bridge, or ford, or ferry, is advantageous, not only for the bringing of produce and goods to the market, but because the trade of a market is much increased when it is thus situated in the stream of traffic.

The size of markets.

The size of a market in proportion to the population depends greatly on whether the business is to be wholesale or retail, for in the former case, where traders purchase in bulk for re-sale in the suburbs (as in the principal London markets), it is obvious that a much less space will be needed than would be required for the retail disposal of an equal quantity of merchandise. The choice of design depends principally on the purpose for which the market is required, on the climate, and on the amount of money available. The simplest and cheapest kind of market buildings consists of covered sheds, or arcades, open at the sides, erected in an open space suitably levelled, paved, drained, and lighted. Such structures are most suitable for fruit, vegetables, and flowers, and may be, and often are, used as general markets also; but the extent to which such an arrangement is expedient depends mainly on the climate. In warm or dry countries it may be sufficient to provide thus a shade from the sun; and such covered sheds, supplemented, perhaps, by awnings, are often found in continental and eastern countries. In cold or damp climates, enclosed and covered markets are desirable; and in very hot countries walls and roofs constructed so as to exclude the heat may be equally necessary.

Choice of design.

Sheds or arcades.

Awnings.

Enclosed markets.

Open market-place.

An open market-place is often kept clear as a plaza or square; and on other than market-days is used as a place of assembly, or as a review-ground for troops. Where such use of the space is frequent, portable booths of wood and canvas can alone be allowed; but often improvements may be made with advantage in the paving, draining, and lighting. If an unencumbered space is wanted only on rare occasions—annually, for instance—light buildings might be constructed of iron and wood in such a manner that they could be easily taken down and refixed.

Booths.

Removable buildings.

Area of market, how divided.

In the design of a covered market, as of most other structures, it is economical and convenient to divide the area to be covered into rectangular or other regular figures of similar dimensions, and (if the site be of an uneven shape) either to leave irregular corners open, or to fill them with specially-designed structures. By thus having the various parts of simple shape, with as little variety as possible, and interchangeable, the building can be made at a minimum cost, and will best allow of extension afterwards. Such an arrangement can be carried out in various ways: if the area be large, separate but similar pavilions may be placed side by side, or grouped round a central structure; the spaces between the pavilions being used as

Buildings of regular shape.

Buildings arranged in blocks.

either covered or uncovered avenues. Architectural effect may be given by making the central structure higher than the pavilions, and surmounting it with a dome and flagstaff. Another plan, if the shape of the site favour it, is to cover the area with a series of parallel roofs, as is done sometimes in a railway-station. A fountain placed under the centre of a dome, or where avenues converge, will enhance the symmetry of the design, and in warm climates be pleasant and refreshing.

Fountains.

Roofs of moderate span. *See* IRON ROOFS, *in Part II.*

There is no necessity for roofs of large span (which are expensive) over a market-building, for as a market is properly and conveniently divided into avenues, supporting columns can be placed near together, without interfering with the circulation of persons, or with the business of the traders; a market, in this respect, differing from railway-stations and other buildings, where it is often very important that the entire width enclosed shall be unobstructed by columns. The details of the design depend also to some extent on the nature of the business to be transacted; whether wholesale or retail; whether for corn, meat, fish or vegetables; or whether as a general market for all kinds of provisions. Frequently in a general market not only provisions but—where the space allows—all kinds of wares for domestic use are sold; and it is in cases of the latter kind that galleries are useful and profitable. As the amount of rent for stalls is measured by the area, and as galleries in a building already enclosed need not cost in proportion to their area so much as the original building, a valuable addition to the revenue may by their use be obtained. The expediency of having galleries must, however, be decided according to the nature of the commodities, the accommodation already provided, and other circumstances of the case. In some English and Continental markets, galleries are found extremely useful, and well frequented for such wares as clothing, haberdashery, seeds, hardware, confectionery, toys, and birds. As market buildings are sometimes rendered available for public meetings or performances, galleries, useful for such purposes, afford a remunerative addition to the revenue. The galleries should be continued on all sides of the building, or staircases provided at each end, and the staircases should be wide, conspicuously placed, and easy of ascent.

Design depends on kind of trade.

General markets.

Galleries.

Useful for sale of small wares.

Or for public meetings.

Staircases.

Where land is valuable, and where, therefore, it is desirable to utilise to the utmost the area occupied, cellars may be provided underneath the market, and let for the purpose of storage to the

Cellars.

traders who occupy stalls; or they may be used as a wholesale market, or may be let separately to wine-merchants, potato-dealers, or others. If cellars are constructed below the market, special arrangements must be made for paving, lighting, draining, and ventilating them, and for giving access to them from the market. Openings from the outside of the market to the cellars must be provided also; and in some cases it is found desirable to have sloping roadways by which carts may obtain access, or even lines of railway, as in the London Meat Market. Where a market is built on sloping ground, the entrances may be arranged on one side at the cellar or basement level, with flights of steps upwards to the market floor; and at the other side on the floor level with flights of steps down to the cellars. Although cellars will, in most cases, prove profitable, there may be cases—as where meat and vegetables are brought in daily, and storage room has, therefore, little value—in which the construction of cellars might not produce revenue enough to defray their cost.

Access to cellars.

A sloping site utilised.

All the avenues of the market should be wide, and although much space, valuable for stalls, may apparently be thus occupied, the free circulation in the wide avenues renders them really remunerative. The exact dimensions depend somewhat on the size of the market and the nature of the commerce; but it is seldom that any passage between stalls should be less than 12 ft. wide, and the main avenues should be from 18 ft. to 25 ft. wide, and even wider if used as thoroughfares for vehicles. The perambulation of possible purchasers is much encouraged, and the business of the trader increased, by so connecting the avenues and galleries that passengers are not obliged to retrace their steps, but may pass on and away as they please. Stalls situated in a blind alley (*cul-de-sac*) are out of the stream of traffic, and lack custom. Where tolls are collected, it is necessary to hold command of the gates or doors by which goods can be brought in, but, subject to the exigencies so involved, numerous points of entrance and exit are desirable.

Market avenues should be spacious.

And continuous.

Market gates.

The outside frontages of a market may be utilised if necessary by rows of stalls—connected or not with those within—facing outwards; the stalls projecting under pent or overhanging roofs. If the surrounding streets are valuable as business sites, the outside frontages of the market may be utilised for shops or offices, and a revenue obtained higher than that sacrificed in the space thus abstracted from within; but such a plan generally involves a departure from the

Outside frontages.

Utilised for shops.

principle of a public market, and sometimes obstructs the approaches. If the market be situated in the centre of a large open area which affords, outside the market, more space than is necessary for traffic, the available area may be paved and used as a wholesale market; and on the days when it is not so used, as a retail market for goods which will bear exposure. It is always desirable to have space outside the markets or in neighbouring streets as standing-room for carts, carriages and horses. In choosing a design for a market (as for any public building), where highly ornamental or imposing elevations may be suggested, the suitability of such designs for the special site in question must be considered. It not unfrequently happens that designs seen to advantage on paper quite fail of effect when executed, if the market be surrounded by narrow streets or lofty houses which shut out the view.

Open area outside a market.

Imposing designs sometimes fail of effect.

The material best suited for market-buildings of course depends largely on what is most easily obtainable in the locality. If masonry or brickwork can be executed well and at moderate cost, the walls may be built of stone or brick, and the architectural details of the façades and elevations designed accordingly. But iron is peculiarly suitable for market buildings; and even where brickwork or masonry can be obtained, such materials are often best confined to the foundations and dwarf walls on which iron columns stand. If the framework be thus entirely of iron, the spaces between the columns may be treated in various ways. Slightly-built brick walls with openings for light and ventilation may be placed to act merely as screens; or by placing only *grilles* or iron railings between the columns, the air may be freely admitted; this method, subject to the exigencies of climate, being often adopted in meat or cattle markets where ventilation is specially needed. In either case the light can be regulated by louvres (*persiennes*) of glass, wood, zinc, or iron; or by awnings, or curtains. Tiles, slates, zinc, galvanised corrugated iron, and glass are the materials used for roof covering. In many countries, where building materials have to be imported, tiles are found effective both in appearance and durability: they are made much lighter than formerly, and are easily fixed. Slates are serviceable in a climate like that of England, but they are fragile for export. Zinc is the best metallic covering; galvanised iron, though cheap and effectual, being not very durable in cities unless periodically painted. The amount of glass must be determined not only by the light required, but by the temperature of the climate. Instead of brickwork,

Masonry or brickwork.

Iron.

Screen walls.

Ventilation.

Light.

Roofing materials.

See, in Part II., GALVANISED IRON.

iron panels, tiles, or terra-cotta can be used with good architectural effect; and in some cases, where the sides of the market are shaded from the direct rays of the sun, an iron framework is entirely filled in with glass.

Iron and glass.

Although traders are certain to arrange their stalls according to individual choice—and too much minute detail should therefore be avoided in the design—it is desirable to maintain a general uniformity of appearance, and, by making the interior suitable for its purpose, avoid the necessity of unsightly additions afterwards. Thus the supporting columns should be povided with brackets, or with the means of attaching brackets at a uniform level; and if considerable weights have to be suspended—as at butchers' stalls—sufficient strength should be given to the various supporting parts. In warm climates, provision should be made for hanging curtains, or awnings; and large openings should be made at a suitable height in the walls to promote ventilation.

Market stalls.

Uniformity desirable.

Stall fittings.

Hanging curtains provided for.

The cost of covered markets depends on their area and height, and the character of the design. In estimating the cost of such structures, the "square" (equal to 100 superficial feet) is generally adopted by English engineers as the unit of measurement; but as buildings may be erected to a great height, and it is obvious that then the expenditure for covering a certain superficial area will be increased, it might appear as if the cost would be more fairly measured according to the cubic space enclosed by the walls from the floor to the ridge of the roof, as is usual in stating the cost of ordinary buildings. Thus, in England, the cost of cottages will range from 5d. to 7d. per cubic foot, of villas from 8d. to 10d., and of mansions from 1s. to 1s. 6d.; but it is because, in buildings of these kinds, the sizes of rooms, the numbers of doors, windows, and the other fittings which determine the expense, bear a not very variable proportion to the space enclosed, that such moderate limits of difference will be found to embrace the cost of almost every kind of dwelling-house. But when public buildings of so variable a character as markets are designed, in which the interior number or weight of parts bears no fixed relation to the space enclosed, and when, moreover, buildings are made so high as to add greatly to the cubic space without adding proportionately to the cost, then any application for purposes of estimate of a fixed price per cubic foot will be found fallacious and misleading. It is impossible, therefore, to give any such standards of cost; and the superficial area

Cost of covered markets.

Calculated according to area.

According to cubic space enclosed.

As customary for dwelling-houses.

Superficial area the best measure.

becomes a safer measure if the qualifying circumstances be borne in mind. The height which is suitable depends largely on the climate and the nature of the commodities, both of which circumstances determine what amount of ventilation is necessary.

Preparation of site.

Levelling and draining.

Macadam paving. *See page 247.*

Granite. *See page 246.*

Asphalte. *See page 227.*

Lamps and water-supply.

For the purpose of estimating the cost of markets, the preparation of the site may be separated from the erection of the building. If an open market-place only is to be formed on a site already clear, levelling and draining will probably cost from £2 to £4 per square. The kind and cost of paving of course depend upon the materials obtainable. An entirely new, rolled, macadamised surface on a suitable substratum would in England cost from £4 to £5 per square. Paving, with granite setts upon concrete, costs in England from £6 to £8 per square yard. Asphalte (of the modern kind used in street paving) on concrete forms a clean and durable flooring for a market-place; a thickness of 2 in. on 6 in. concrete costing from £8 to £10 per square. For the inside of a market where there is no traffic of vehicles, asphalte ¾ in. thick would suffice, at a cost of from £4 to £6 per square. The cost of lamps and of supplying water would in most cases have to be added in estimating the cost of an open-air market.

Cost of sheds of simple design.

Strongly-built unenclosed markets.

Cost of flooring.

Cost of enclosed markets. *See, in Part II.,* IRON ROOFS & BUILDINGS.

Assuming average prices of material, iron sheds or arcades or bazaars of the simplest kind from 18 ft. to 25 ft. wide, open at the sides, and from 12 ft to 20 ft. high, would cost from £8 to £14 per square; and similar buildings, enclosed at the sides with wall-screens of corrugated iron, and having roof-covering of iron and glass, would cost from £12 to £18 per square. Stronger buildings, as suitable for unenclosed markets in a large city, cost from £15 to £25 per square. The foregoing prices are exclusive of the preparation of the site, of flooring, of interior stalls or fittings, or of water and gas supply. A floor of concrete with a cement-surface costs from £3 to £4 per square; wooden flooring on sleeper-walls and timber joists, from £6 to £8 per square; wooden blocks bedded upon concrete, from £7 to £10 per square. Enclosed markets strongly constructed of iron, with wall-screens of brickwork or brickwork combined with iron grilles, cost, including flooring and lighting, from £50 to £80 per square, and when lofty or imposing designs are carried out, the cost reaches £100, the exact price depending on the height of the structure and on the character of the design. It is obvious, however, that on a given area the possible range of expenditure is very wide, and it will be found that even the limits of cost above stated do not include markets of the most expensive kind. In London, for instance, where space is valuable, where a constant and enormous trade has to be carried on, and where, therefore, high rents can be paid, it becomes necessary and remunerative to construct buildings of the strongest kind, and to provide every adjunct for facilitating the commerce in commodities. Moreover, in a capital city a certain architectural display is demanded, which adds to the cost. The more modern of the London markets have lofty and imposing elevations, strong walls of brickwork with ornamental masonry, massive iron gates, cellars, stalls enclosed as two-storied shops with staircases, offices, cranes, elaborate stall fittings, and, including all these and the numerous other appurtenances of a public market, and everything but the purchase of land, the cost reaches £200 per square.

Expensively-built markets.

London markets examples of high cost.

Even after a suitable market has been erected on a well-chosen site, its success, both financially and in popular estimation, depends greatly on the management. The principle of a public market demands free-trade and competition; and care must be taken that the normal tendency of the traders to combine against the interests of the public is not in any way assisted or encouraged by the regulations. It is generally disadvantageous to farm out the tolls to one lessee; to allow the stalls to be occupied by cliques or trades-unions, to the exclusion of the independent trader; or to make conditions too onerous for traders of small capital.

The management of markets. *See page 23.*

Free-trade.

Onerous conditions to be avoided.

Bye-laws are necessary for the due management of a market: such laws having reference to the days and hours of business; the periods for which the pens or stalls will be let; prevention of over-crowding or other cruelty to animals; the tariff of tolls, and the terms of holding; prohibition of obstruction in the avenues of the market; the price or conditions on which water and gas will be supplied; conditions as to cleanliness and the removal of refuse; the kind of commodities which may be sold, and limits, if need be, as to bulk or weight; the inspection of weights and measures; the preventing the sale or exposure of unwholesome provisions, or the undue storage of perishable food; the standing-places for horses or carriers' carts; the extinguishing of fires and lights; the plying for hire of porters and others; the hawking and crying of goods for sale; and penalties for infringement of the bye-laws.

Bye-laws.

Regulations and prohibitions.

Penalties.

A market may, however, be over-managed, and if, by too strict regulations, the traders are hampered in their business or purchasers subjected to excessive control, there is a risk of the market becom-

Over-management undesirable.

ing neglected. Sometimes such over-regulations arise from philanthropic motives, or from over-strained sanitary precautions, but they are none the less prejudicial to the success of the undertaking; and, within due limits, the rules should be framed as far as possible to accord with the habits and traditions of the people.

Judicious framing of rules.

Information necessary for designing markets.

It will be evident from the wide range of costs given on page 272, that a full knowledge of the circumstances, of the class of buildings required, and of the funds available, is necessary to the proper designing of a market building; and for enabling capitalists, engineers, contractors, or municipal officers to estimate the cost and revenue of the undertaking. The information required may be summarised as follows:—

Map of town.

1. A map of the town, with the principal streets, railway stations, existing markets, and public buildings marked upon it, and showing the site chosen for the market.

Plan of site.

2. A plan on an enlarged scale of the site of the market and the approaches to it; and a description of the nature, style, and height of the buildings in the neighbourhood of the site.

Site described.

Rights affirmed.

Foundations, drainage, and water-supply.

3. The condition of the site, such as whether it is cleared and levelled, or whether buildings or other obstructions have to be removed. The proprietary rights, if any, which exist with regard to the land, and the terms on which they are to be dealt with. The nature of the soil and its suitability for foundations, the drainage system which exists in the neighbourhood of the site, the sewers or drains (as indicated on a plan) to which the waste-water and the rain-water from the roofs must be conducted.

Clearing of site.

4. If the new building is to occupy the site of an existing market, the arrangements proposed for the removal of the old structure, and for temporary accommodation during the rebuilding.

The kind of trade to be carried on.

5. The service for which the market is intended; whether for wholesale or retail trade; the nature of the commodities; and whether galleries or cellars are required.

Population.

Existing markets described.

6. The present population of the town, its past rate of increase and the indications of increase for the future; the size, shape, and appearance of existing markets; the nature of the business transacted in them, and the rates of toll or rent; and the reasons which have suggested the necessity or advantage of the proposed new market.

Climate.

7. The nature of the climate, the frequency of rain, and the occurence of heavy rainfalls or snow, the extreme variations of

temperature, the direction of cooling winds, the force and direction of heavy winds or hurricanes, and such other particulars as may determine the mode of covering, lighting, and ventilating the building, and the removal of rain-water.

Building materials.

8. Particulars, as already directed, concerning the materials for building and the timber for staging which are obtainable in the town or which may be purchased in the country; the kind of workmen and the rates of wages; the facilities for landing and transporting materials; and particulars as to dues, taxes, and imposts.

Dues and taxes.

Water-supply. *See Chap. IX.*

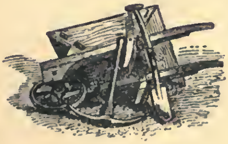
9. The nature of the water-supply, the contiguity of the main to the market, as indicated on the plan; or, if there be no water-works, the wells or other sources in the neighbourhood of the market, and the terms on which the water can be obtained; also the cost of gas or other system of lighting.

Mode of lighting.

Financial.

10. If assistance be asked in providing capital, the nature of the concession to be granted by the municipality, or the terms on which the markets are to be established, should be described, together with the *data* upon which the calculations of revenue and profit have been based.

END OF PART I.



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